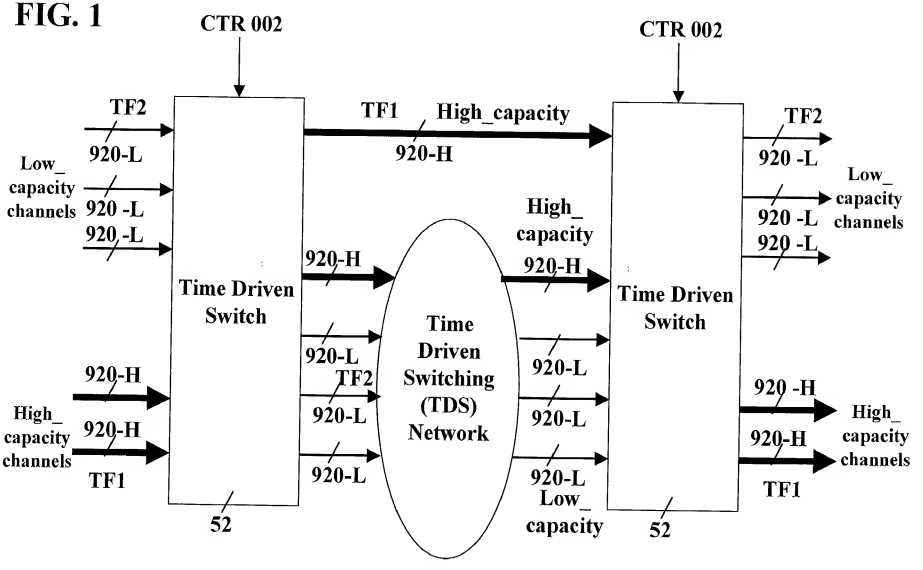
FIG. 1



c = High_capacity/Low_capacity

FIG. 2

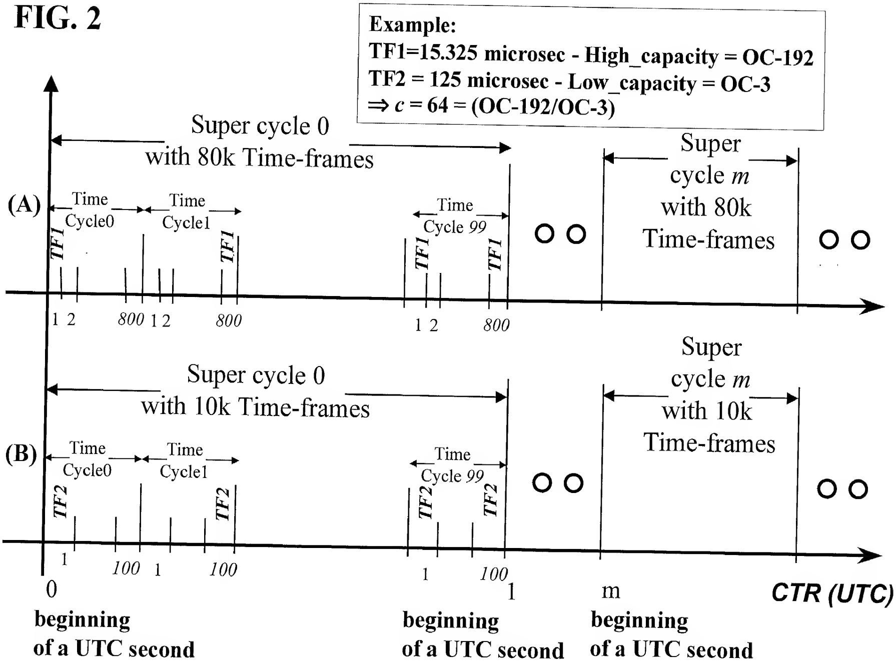

Example:
TF1=15.325 microsec - High_capacity = OC-192
TF2 = 125 microsec - Low_capacity = OC-3
⇒ c = 64 = (OC-192/OC-3)
Super cycle 0
with 80k Time-frames
Super
cycle m
with 80k
Time-frames
(A)
Time
Cycle0
Time
Cycle1
Time
Cycle 99
TF1
1 2
800
800
Super cycle 0
with 10k Time-frames
Super
cycle m
with 10k
Time-frames
(B)
TF2
1
100
0
1
m
CTR (UTC)
beginning
of a UTC second

FIG. 3

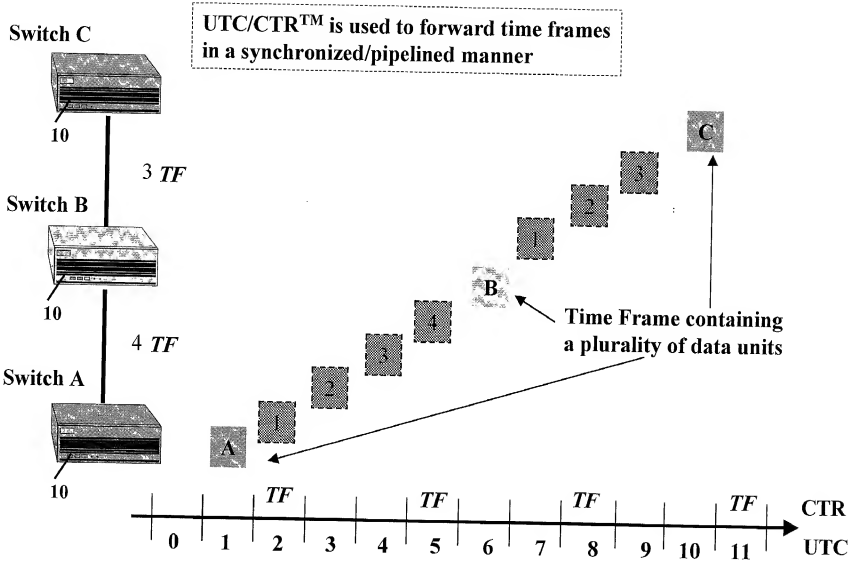

UTC/CTR™ is used to forward time frames in a synchronized/pipelined manner
Switch C
10
3 TF
Switch B
10
4 TF
Switch A
10
A
B
C
1
2
3
4
Time Frame containing a plurality of data units
TF
TF
TF
TF
0
1
2
3
4
5
6
7
8
9
10
11
CTR
UTC

FIG. 4

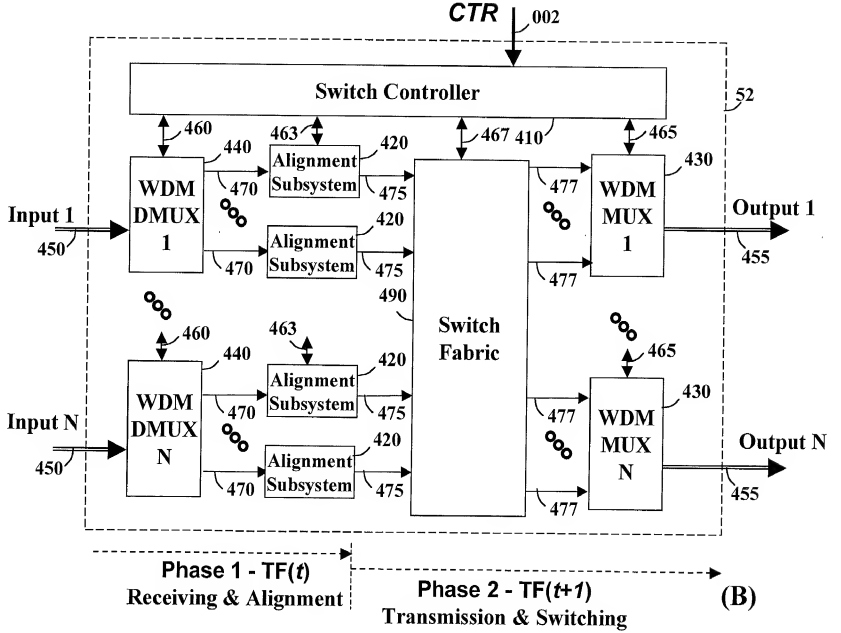


FIG. 5

Two time intervals: SC1_length·TF1 = 1 UTC second

- SC2_length·TF2 = 1 UTC second
- TF2 = (SC1_length / SC2_length) · TF1 = k · TF1, where the time cycles of TF1 and TF2 are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

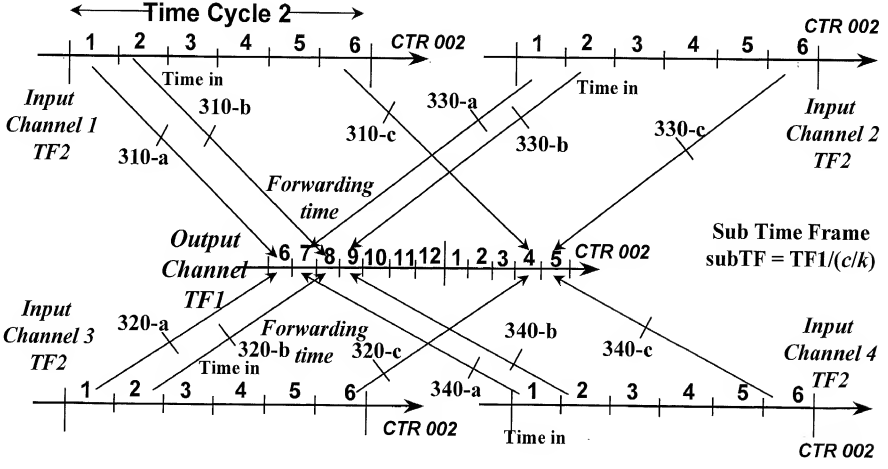


FIG. 6

Two time intervals: ***SC1_length·TF1 = 1*** **UTC second**

- ***SC2_length·TF2 = 1*** **UTC second**
- ***TF2 = (SC1_length / SC2_length) · TF1 = k · TF1***, where the time cycles of ***TF1*** and ***TF2*** are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

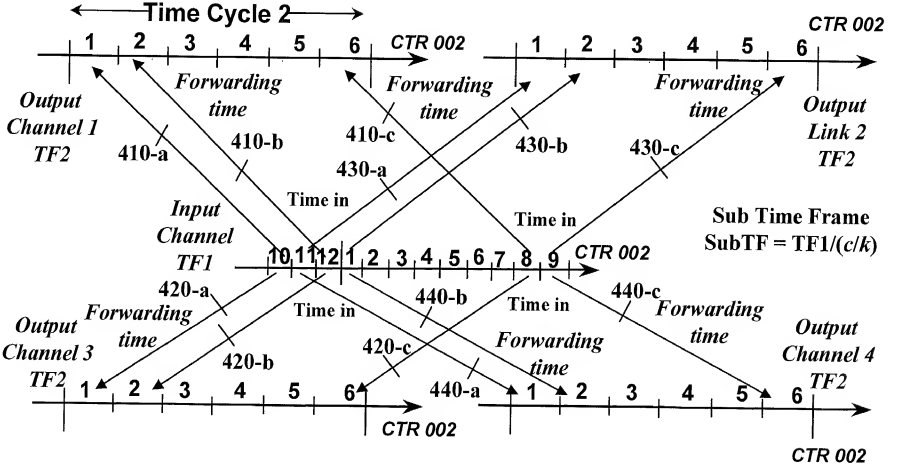


FIG. 7

Two time intervals: *SC1_length·TF1 = 1* UTC second

- *SC2_length·TF2 = 1* UTC second
- *TF2 = (SC1_length / SC2_length) · TF1 = k · TF1*, where the time cycles of *TF1* and *TF2* are aligned with respect to UTC.
  For *k* = 2 and *c* = 4 (e.g., High_capacity=OC-192, Low_capacity=OC-48):

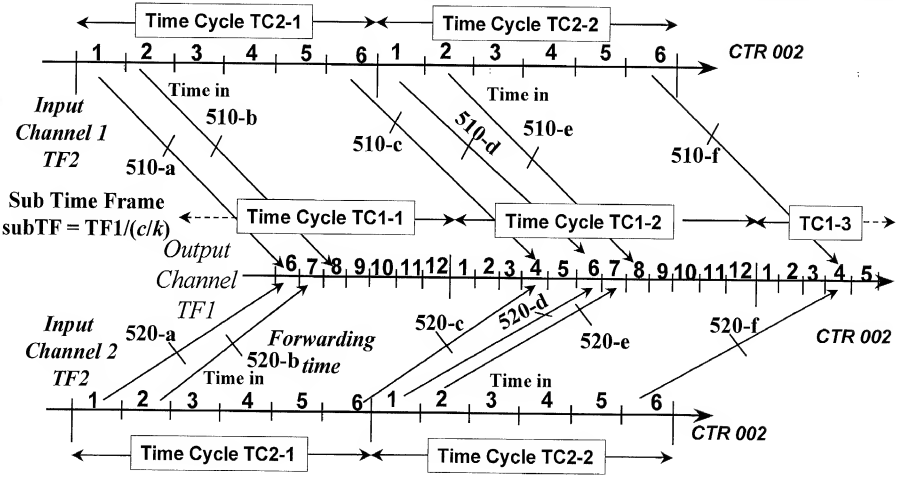
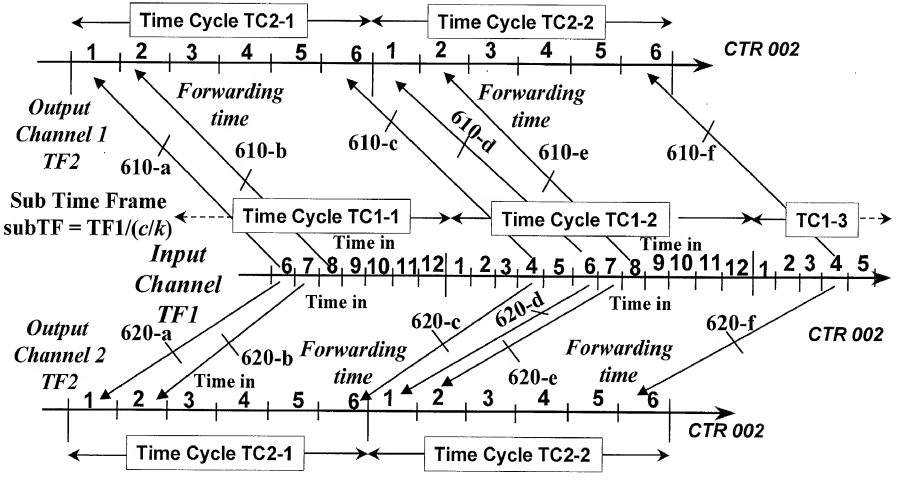


FIG. 8

Two time intervals: *SC1_length·TF1 = 1* UTC second

- *SC2_length·TF2 = 1* UTC second
- *TF2 = (SC1_length / SC2_length) · TF1 = k · TF1*, where the time cycles of *TF1* and *TF2* are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):



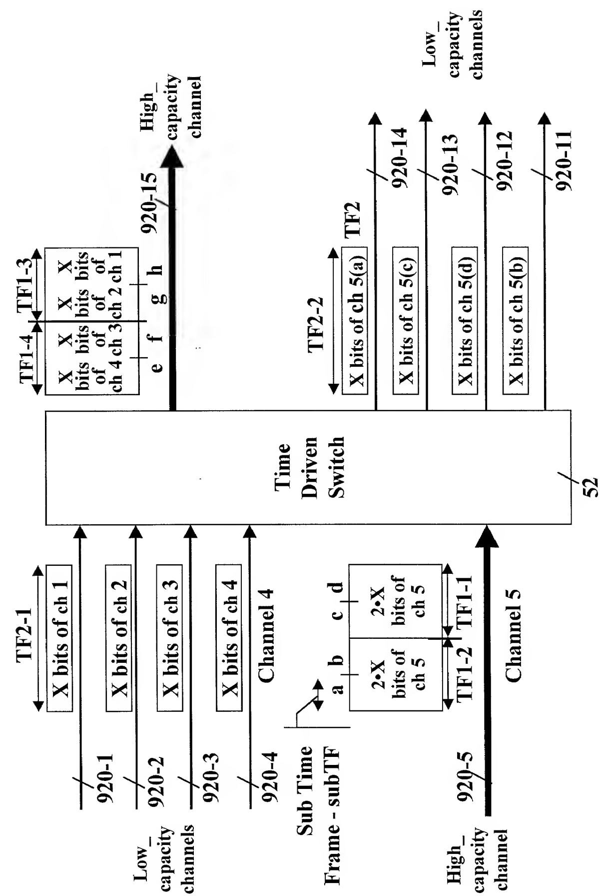

c=4, e.g., OC-192/OC-48
k=2, e.g., 25 microsec/12.5 microsec
Low_ capacity channels
920-1
920-2
920-3
920-4
TF2-1
X bits of ch 1
X bits of ch 2
X bits of ch 3
X bits of ch 4
Channel 4
Sub Time Frame - subTF
a
b
c
d
2•X bits of ch 5
2•X bits of ch 5
TF1-2
TF1-1
High_ capacity channel
920-5
Channel 5
Time Driven Switch
52
TF1-4
TF1-3
X bits of ch 4
X bits of ch 3
X bits of ch 2
X bits of ch 1
e
f
g
h
920-15
High_ capacity channel
TF2-2
TF2
X bits of ch 5(a)
X bits of ch 5(c)
X bits of ch 5(d)
X bits of ch 5(b)
920-14
920-13
920-12
920-11
Low_ capacity channels

FIG. 9

FIG. 10

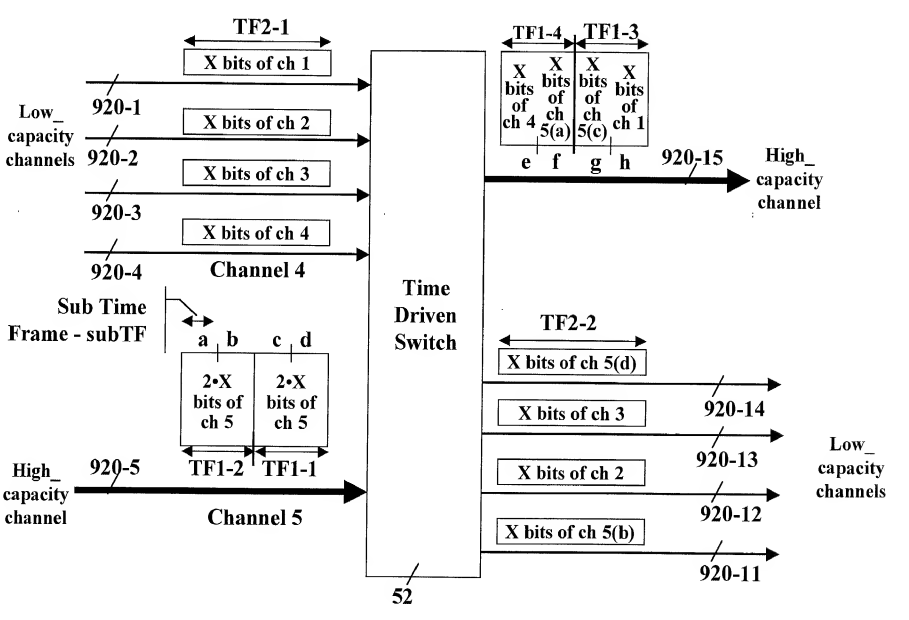


FIG. 11

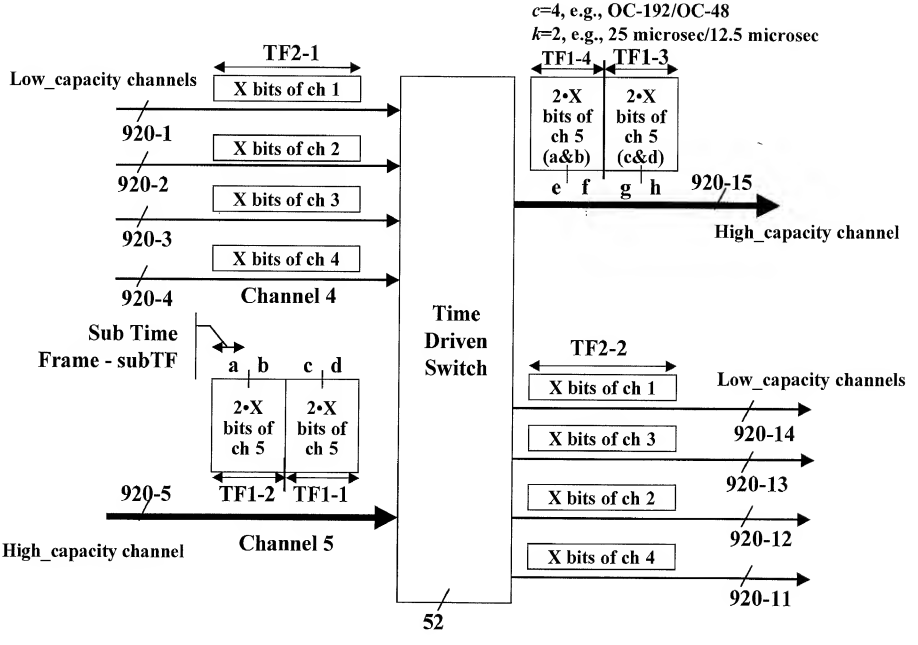


FIG. 12

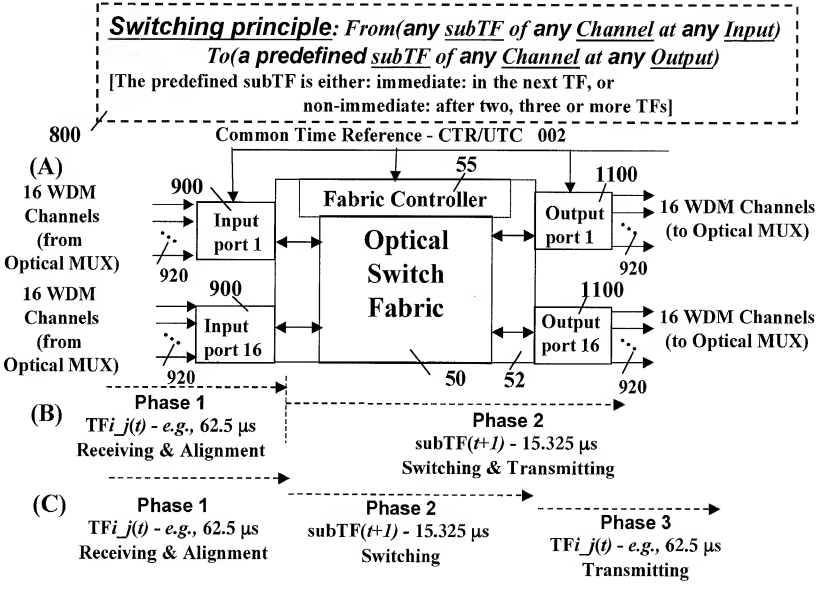


FIG. 13

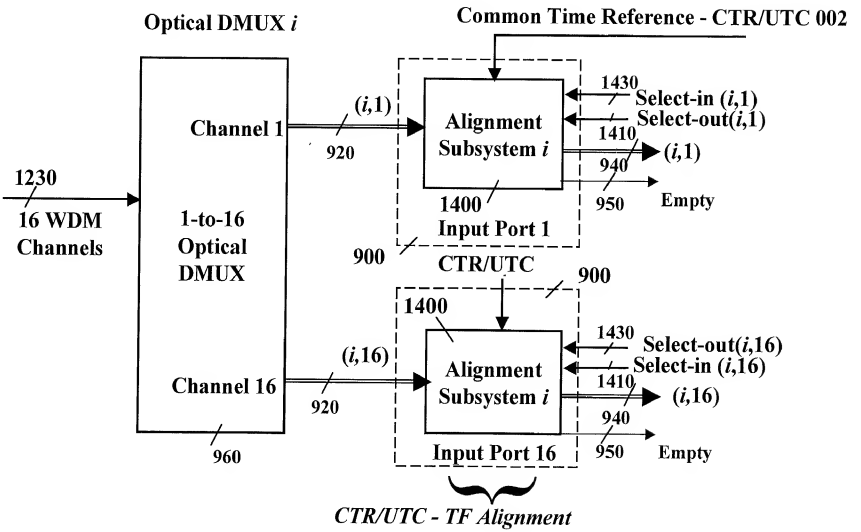
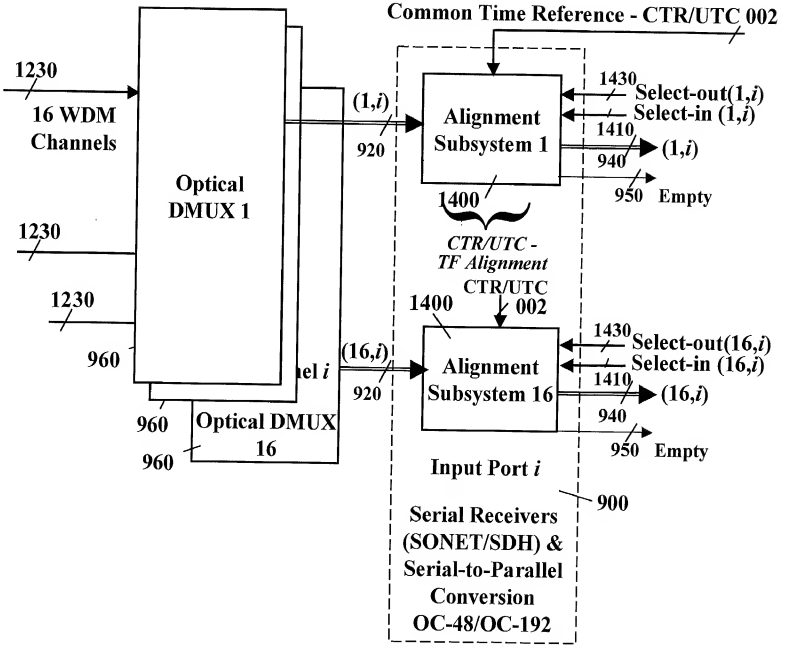


FIG. 14



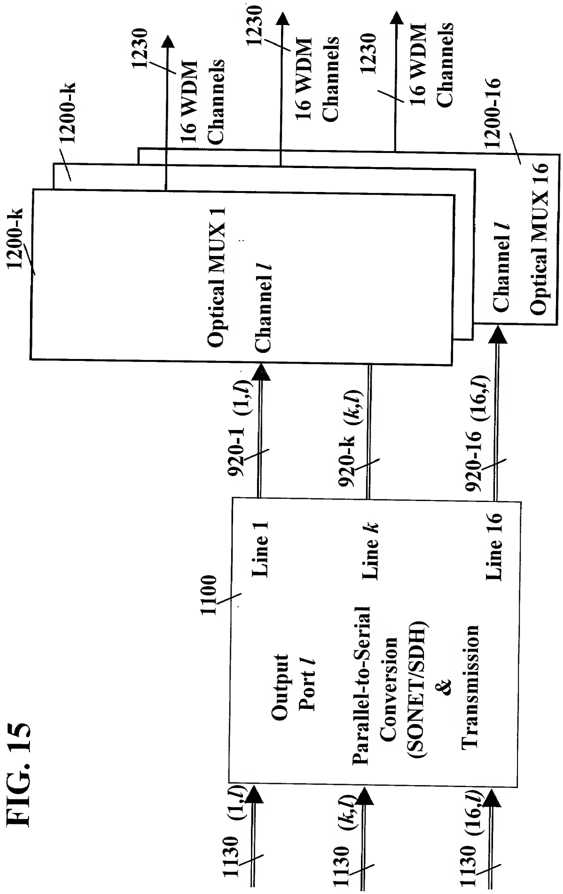

1130 (1,l)
1130 (k,l)
1130 (16,l)
1100
Output Port l
Parallel-to-Serial Conversion (SONET/SDH) & Transmission
Line 1
Line k
Line 16
920-1 (1,l)
920-k (k,l)
920-16 (16,l)
1200-k
Optical MUX 1
Channel l
Channel l
Optical MUX 16
1200-16
1230
16 WDM Channels
1230
16 WDM Channels
1230
16 WDM Channels

FIG. 15

FIG. 16

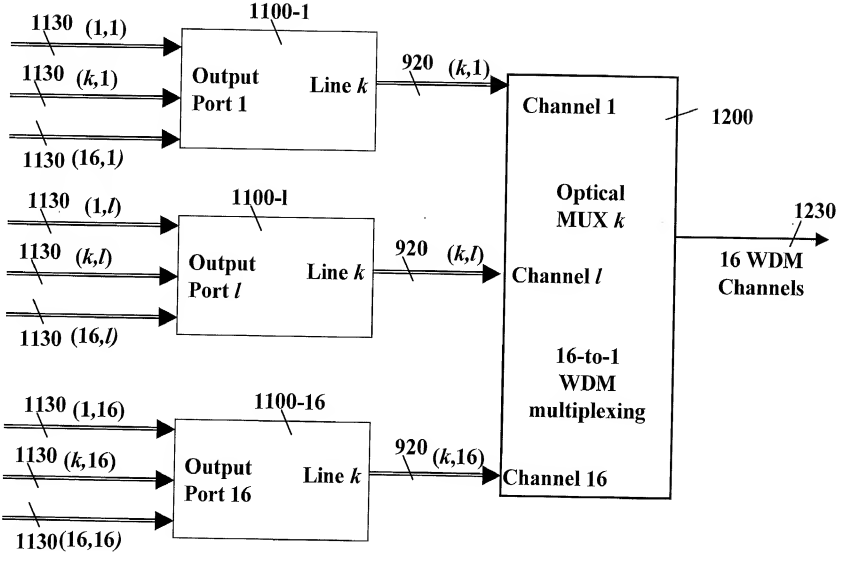


FIG. 17

N: number of input/output channels. E.g., N=256

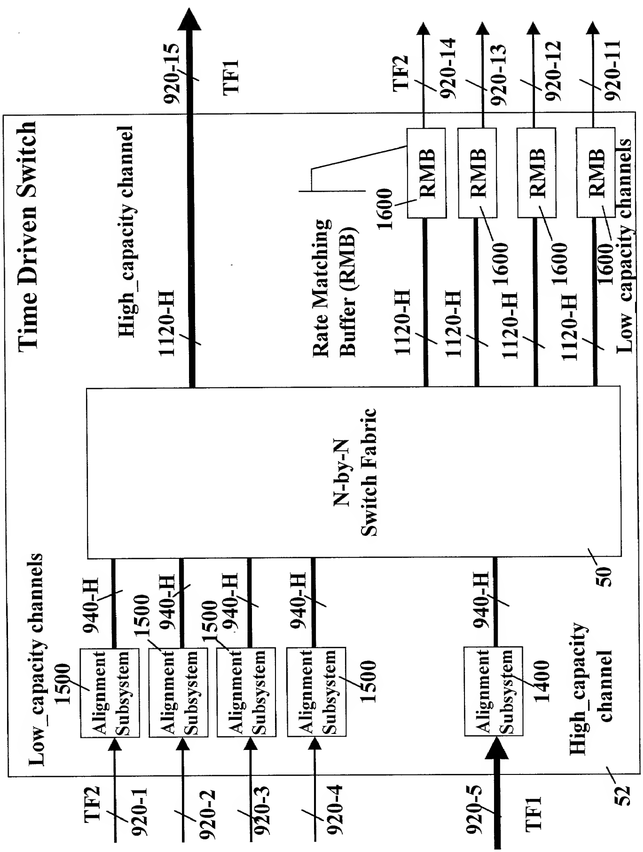
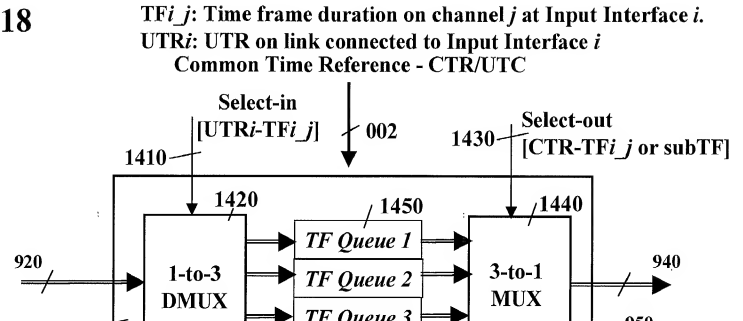


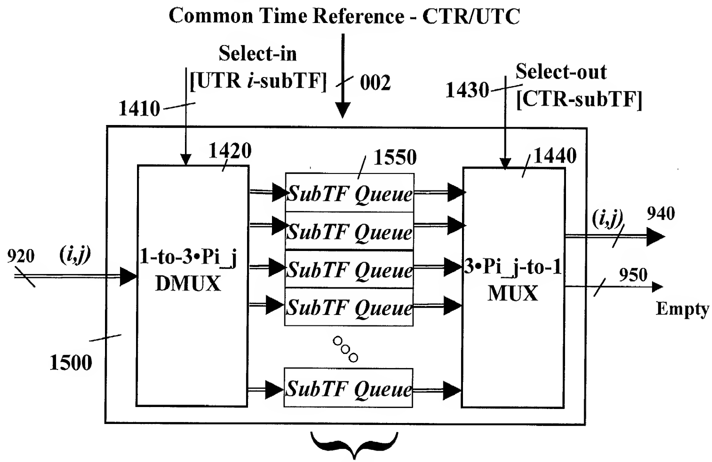
FIG. 18



Alignment Subsystem for Channel *j* at Input Interface *i*
with a Plurality of Time Frame Queues

FIG. 19

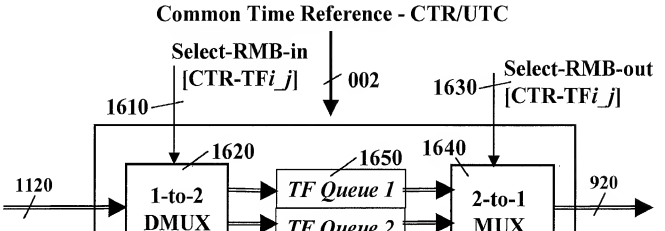
TF*i_j*: Time frame duration on channel *j* at Input Interface *i*.
UTR *i*: UTR on link connected to Input Interface *i*
P*i_j* = TF*i_j*/subTF



Alignment Subsystem for *high capacity* Channel *j* at Input Interface *i*
with a Plurality of <u>Sub-Time Frame Queues</u>

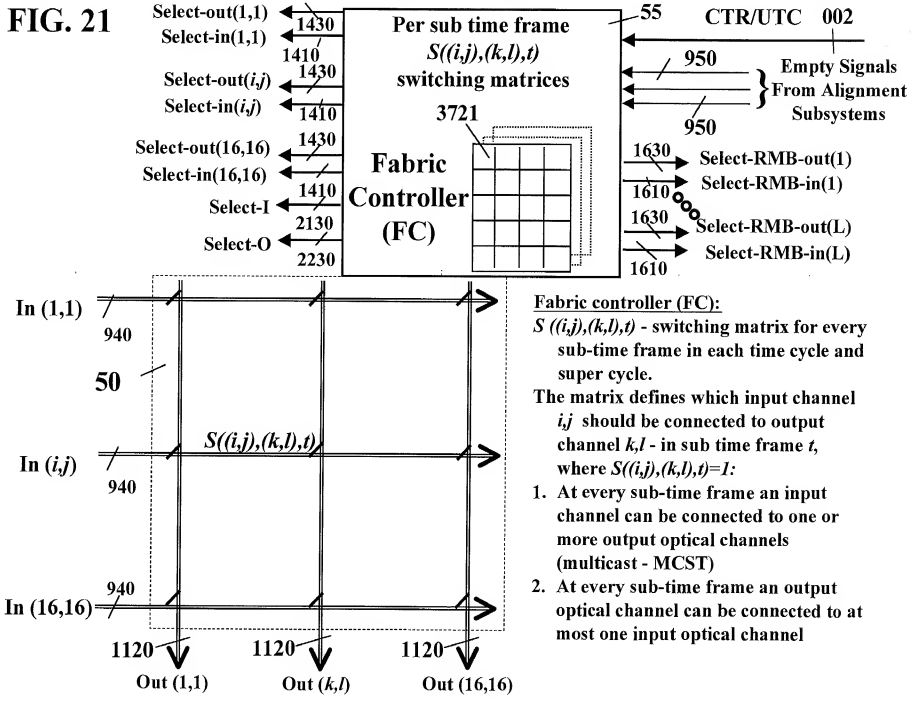
FIG. 20

TF*i_j*: Time frame duration on channel *j* at Input Interface *i*.
UTR*i*: UTR on link connected to Input Interface *i*



Rate Matching Buffer for Channel *j* at Output Interface *i*
with a Plurality of Time Frame Queues
(Also single buffer with dual access memory with single phase switching and forwarding)

FIG. 21



Fabric controller (FC):

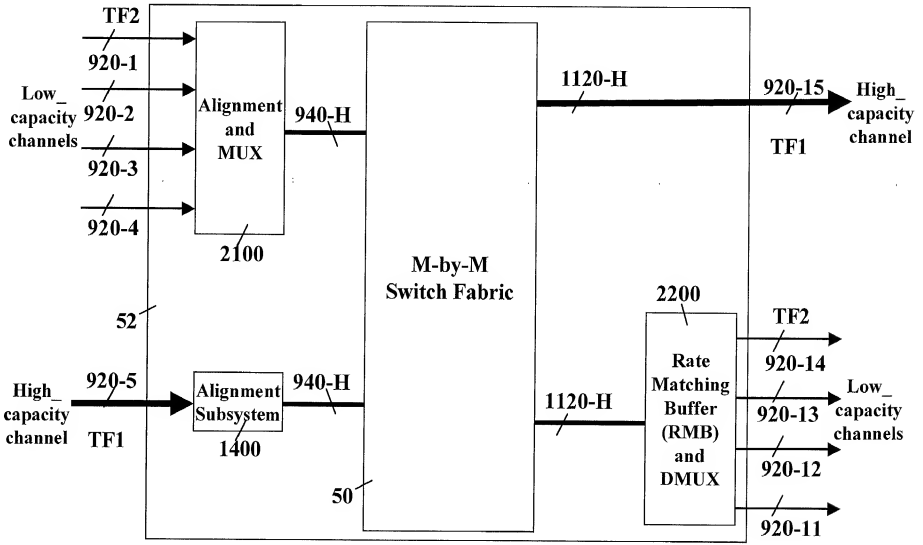
S ((i,j),(k,l),t) **- switching matrix for every sub-time frame in each time cycle and super cycle.**

The matrix defines which input channel *i,j* should be connected to output channel *k,l* - in sub time frame *t*, where *S((i,j),(k,l),t)=1:*

1. **At every sub-time frame an input channel can be connected to one or more output optical channels (multicast - MCST)**
2. **At every sub-time frame an output optical channel can be connected to at most one input optical channel**

FIG. 22

N: number of input/output channels. E.g., N=256
M • High_capacity = N_high • High_capacity + N_low • Low_capacity
M<N



Time Driven Switch

FIG. 23

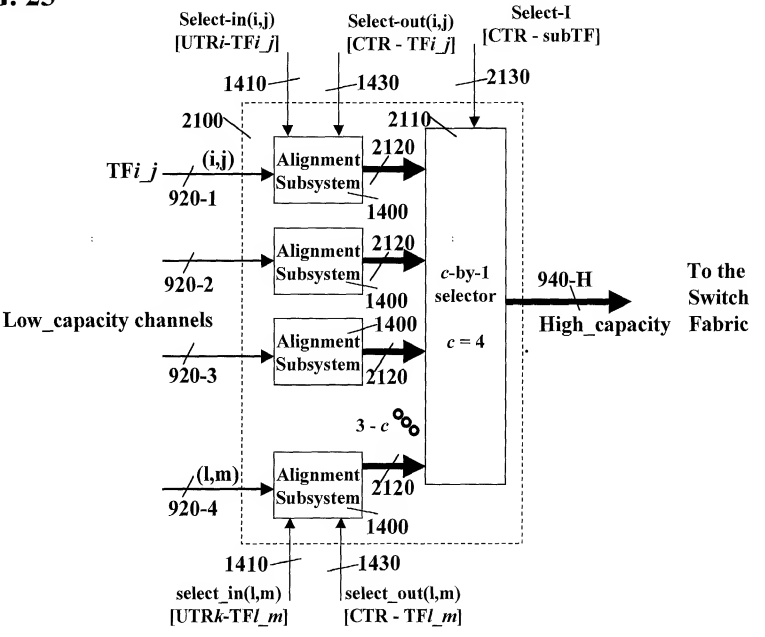

Select-in(i,j)
[UTRi-TFi_j]
Select-out(i,j)
[CTR - TFi_j]
Select-l
[CTR - subTF]
1410
1430
2130
2100
2110
TFi_j
(i,j)
920-1
Alignment Subsystem
2120
1400
920-2
920-3
920-4
Low_capacity channels
c-by-1 selector
c = 4
940-H
High_capacity
To the Switch Fabric
3 - c
(l,m)
select_in(l,m)
[UTRk-TFl_m]
select_out(l,m)
[CTR - TFl_m]

FIG. 24

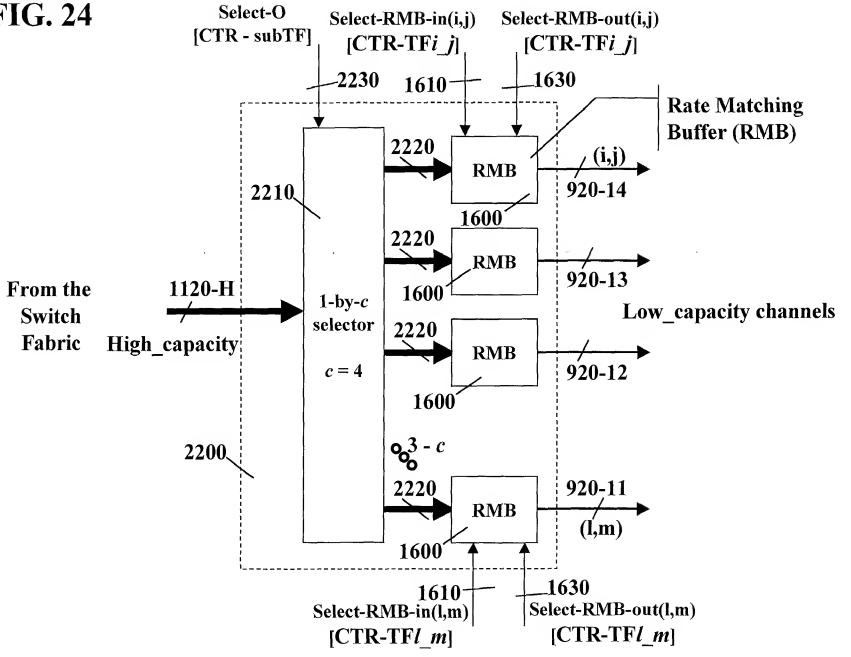
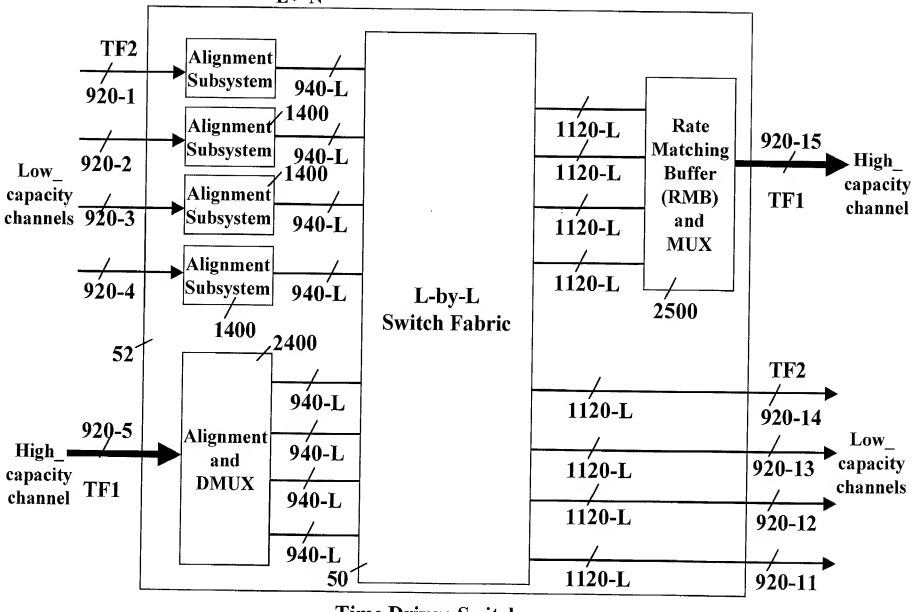


FIG. 25

N: number of input/output channels. E.g., N=256
L • Low_capacity = N_high • High_capacity + N_low • Low_capacity
L > N



Time Driven Switch

FIG. 26

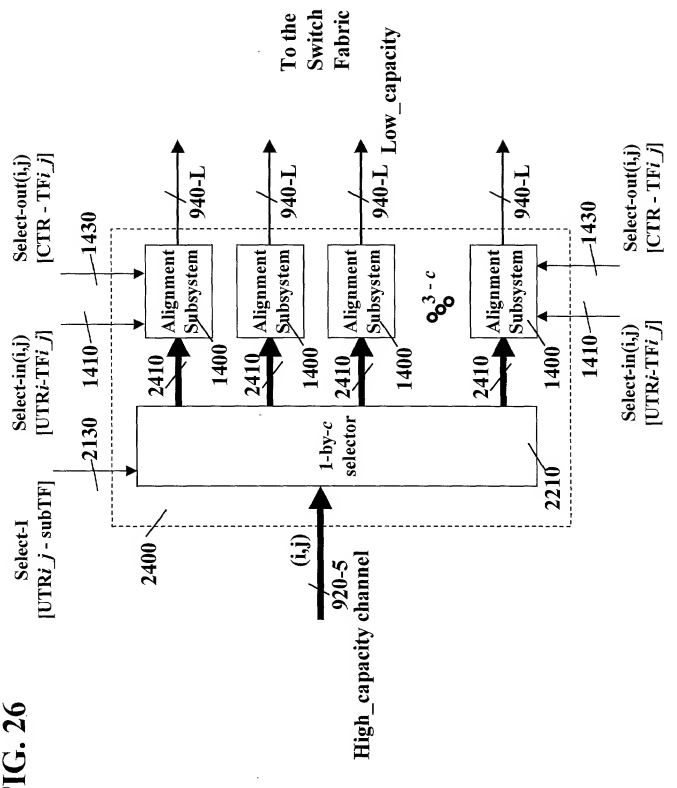


FIG. 27

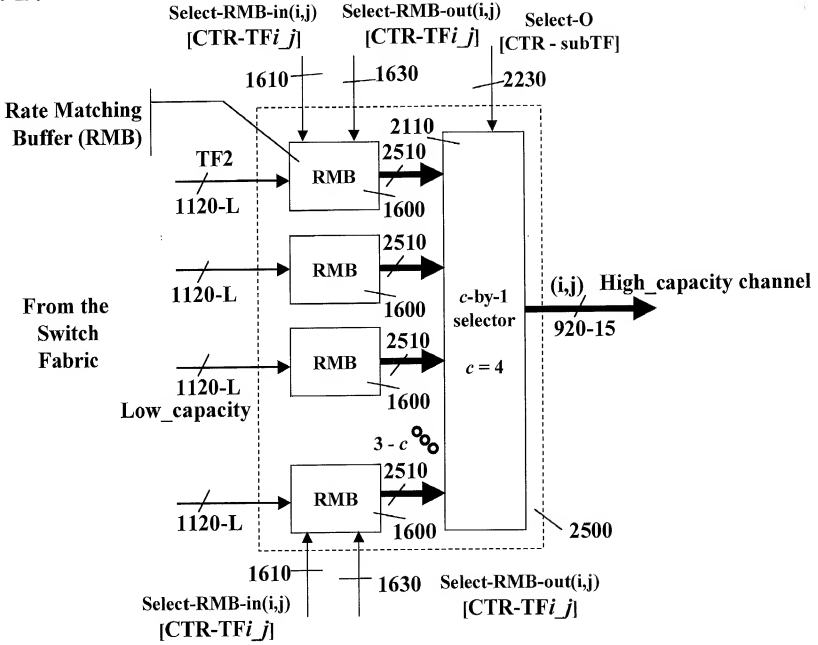
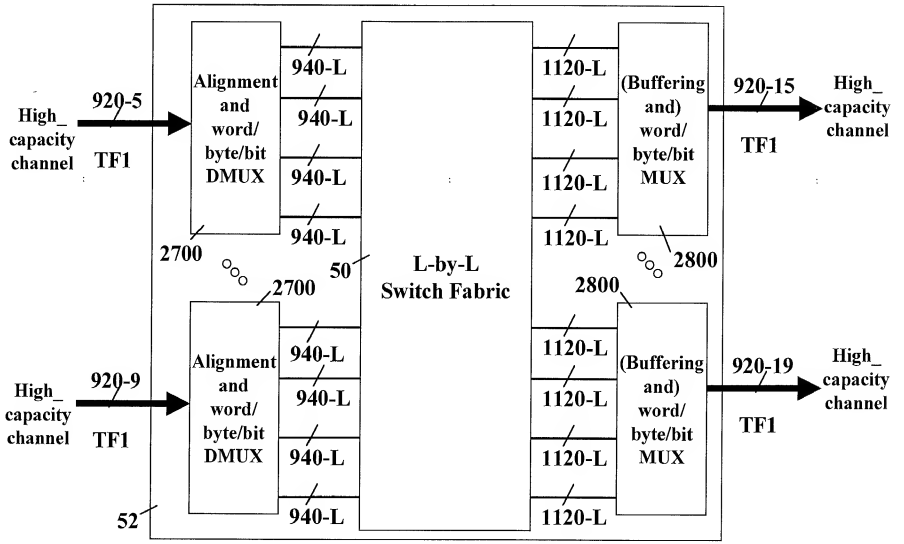


FIG. 28

N: number of input/output channels. E.g., N=256
L • Low_capacity = N • High_capacity
L = c • N > N



Time Driven Switch

FIG. 29

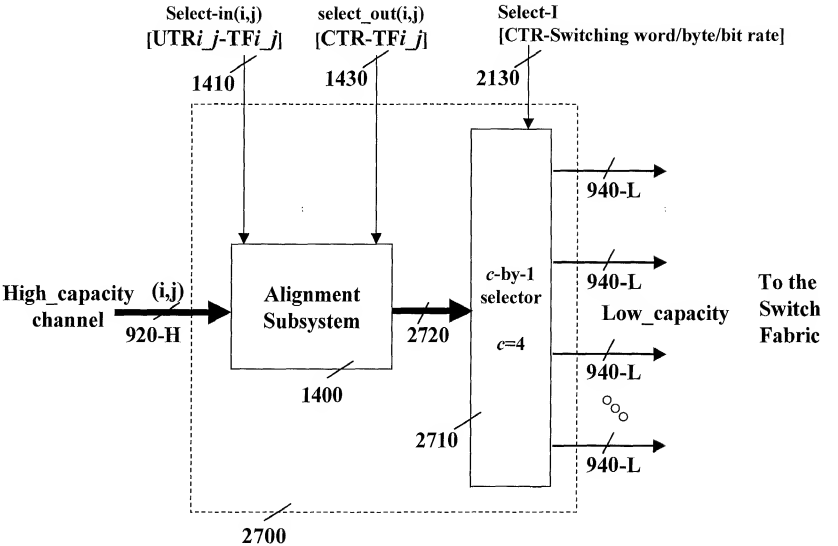


FIG. 30

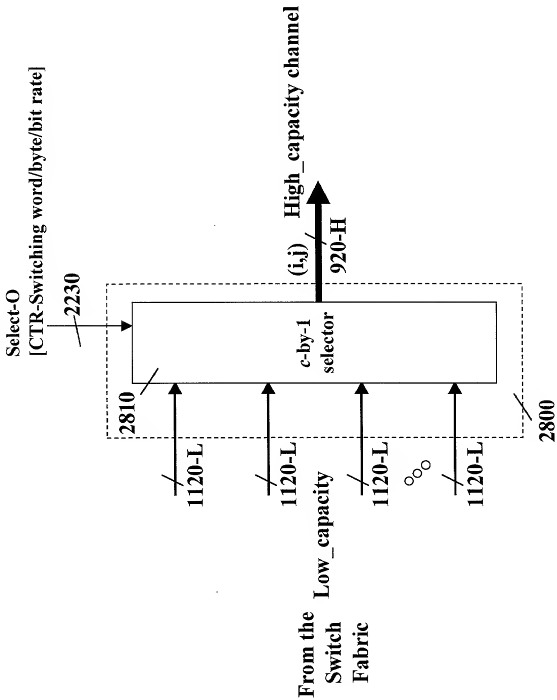

Select-O
[CTR-Switching word/byte/bit rate]
2230
(i,j) High_capacity channel
920-H
c-by-1
selector
2810
2800
1120-L
1120-L
1120-L
1120-L
From the
Switch
Fabric
Low_capacity

FIG. 31

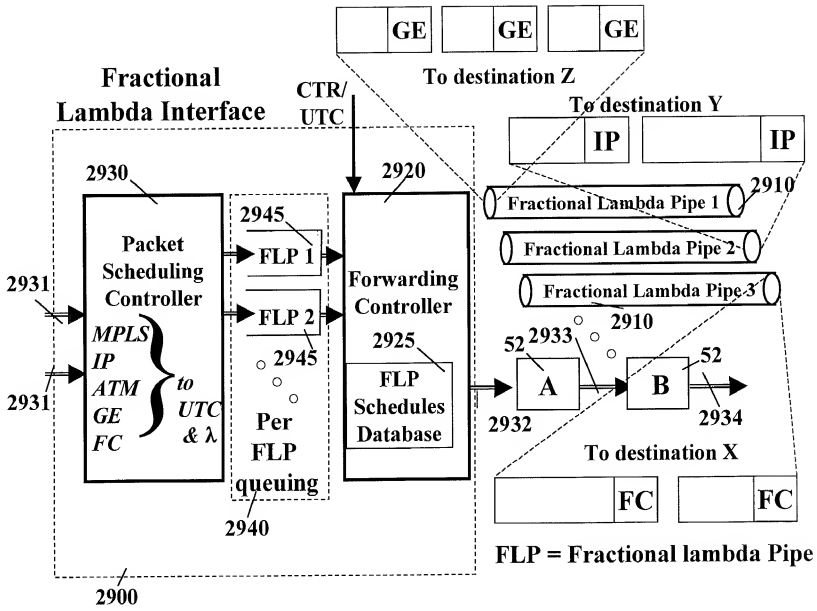


FIG. 32

Channel Capacity		TF Duration	TF Size		STS-1s	TFs/s
51.84	STS- 1	250	1620	1512	2	4000
		500	3240	3024	4	2000
		1000	6480	6048	8	1000
155.52	STS- 3	125	2430	2268	3	8000
		250	4860	4536	6	4000
		500	9720	9072	12	2000
622.08	STS- 12	62.5	4860	4536	6	16000
		125	9720	9072	12	8000
		250	19440	18144	24	4000
2488.32	STS- 48	62.5	19440	18144	24	16000
		31.25	9720	9072	12	32000
		15.625	4860	4536	6	64000
9953.28	STS- 192	7.8125	9720	9072	12	128000
		15.625	19440	18144	24	64000
1000	GE	125	15625	15625	19.3	8000
		100	12500	12500	15.4	10000
		80	10000	10000	12.3	12500
10000	10GE	15.625	19531.25	19531.3	24.1	64000
		12.5	15625	15625	19.3	80000
		10	12500	12500	15.4	100000

FIG. 33

Ch Capacity		*TF Dur.*	*TF Size*	*GE TFs*	*TFs/s*
1000	**GE**	**80**	**10000**	**1.0**	**12500**
51.84	STS- 1	250	1512	0.15	4000
		500	3024	0.30	2000
		1000	6048	0.60	1000
155.5	STS- 3	125	2268	0.23	8000
		250	4536	0.45	4000
		500	9072	0.91	2000
622.1	STS- 12	62.5	4536	0.45	16000
		125	9072	0.91	8000
		250	18144	1.81	4000
2488	STS- 48	62.5	18144	1.81	16000
		31.25	9072	0.91	32000
		15.625	4536	0.45	64000
9953	STS- 192	7.8125	9072	0.91	128000
		15.625	18144	1.81	64000
10000	10GE	8	10000	1.00	125000
		16	20000	2.00	62500

FIG. 34

Ch Capacity		TF Dur.	TF Size	GE TFs	TFs/s
1000	GE	62.5	7812.5	1.0	16000
51.84	STS- 1	250	1512	0.19	4000
		500	3024	0.39	2000
		1000	6048	0.77	1000
155.52	STS- 3	125	2268	0.29	8000
		250	4536	0.58	4000
		500	9072	1.16	2000
622.08	STS- 12	62.5	4536	0.58	16000
		125	9072	1.16	8000
		250	18144	2.32	4000
2488.32	STS- 48	62.5	18144	2.32	16000
		31.25	9072	1.16	32000
		15.625	4536	0.58	64000
9953.28	STS- 192	7.8125	9072	1.16	128000
		15.625	18144	2.32	64000
10000	10GE	12.5	15625	2.00	80000
		25	31250	4.00	40000

FIG. 35

TF Alignment of UTR(j) *to* UTC - with three input queues - principle of operation:
The same queue is not used simultaneously for:
1. Receiving data packets from the serial link, and
2. Forwarding data packets to the switch

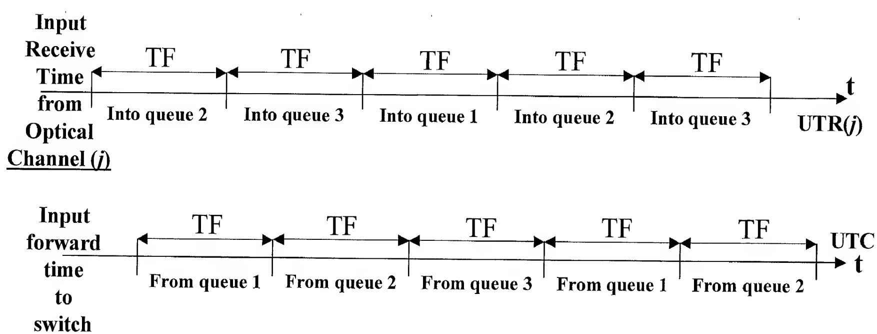


FIG. 36

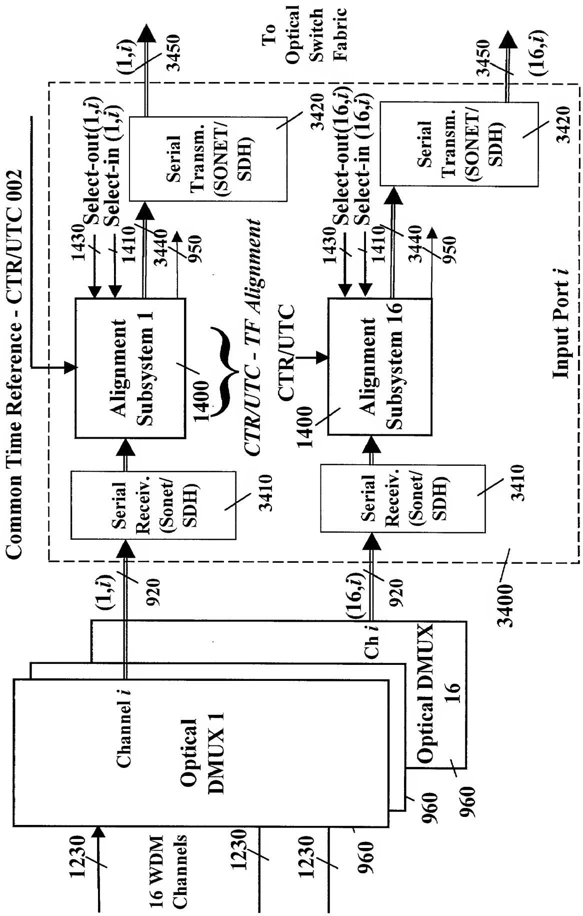

Common Time Reference - CTR/UTC 002
To Optical Switch Fabric
(1,i)
3450
(16,i)
3450
Select-out(1,i)
Select-in (1,i)
Serial Transm. (SONET/ SDH)
3420
Select-out(16,i)
Select-in (16,i)
Serial Transm. (SONET/ SDH)
3420
1430
1410
3440
950
1430
1410
3440
950
Alignment Subsystem 1
1400
CTR/UTC - TF Alignment
CTR/UTC
Alignment Subsystem 16
1400
Input Port i
Serial Receiv. (Sonet/ SDH)
3410
Serial Receiv. (Sonet/ SDH)
3410
(1,i)
920
(16,i)
920
3400
Channel i
Optical DMUX 1
Ch i
Optical DMUX 16
960
960
960
1230
16 WDM Channels
1230
1230

FIG. 37

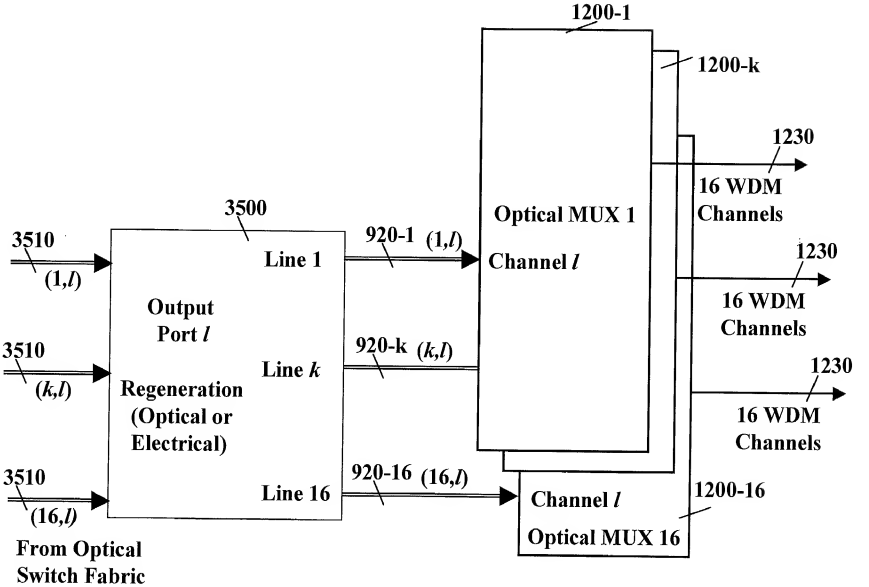


FIG. 38

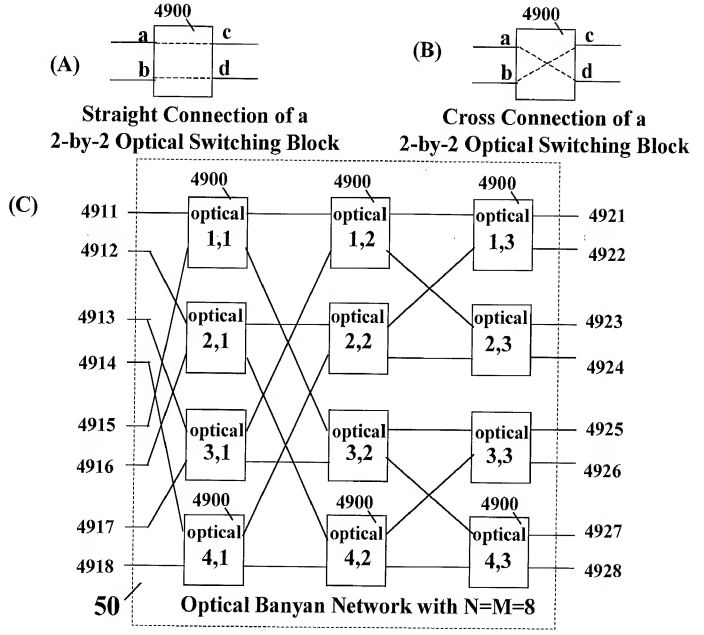


FIG. 39

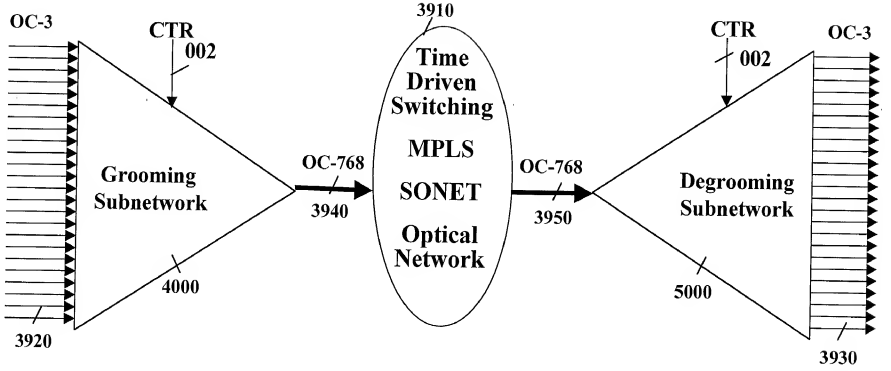


FIG. 40

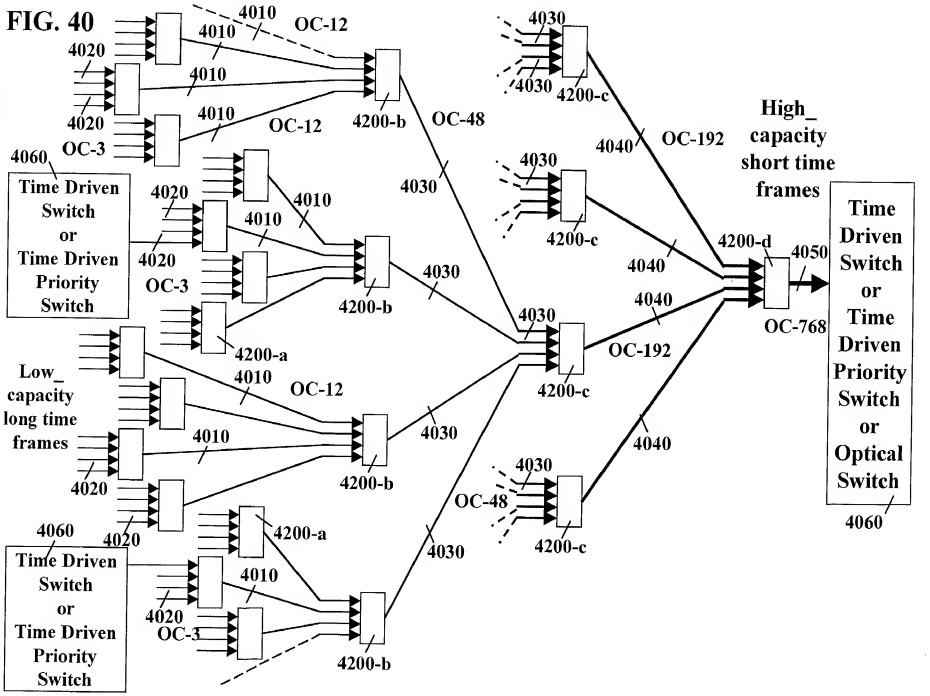

4010
OC-12
4020
4010
4010
4020
4010
OC-12
4200-b
OC-48
4030
4030
4200-c
4040
OC-192
High_
capacity
short time
frames
4060
Time Driven
Switch
or
Time Driven
Priority
Switch
4020
4010
4020
OC-3
4010
4200-b
4030
4030
4200-c
4200-d
4050
4040
4040
4030
4200-a
OC-192
OC-768
Time
Driven
Switch
or
Time
Driven
Priority
Switch
or
Optical
Switch
4060
Low_
capacity
long time
frames
4010
OC-12
4030
4010
4020
4200-b
4040
4030
OC-48
4020
4060
4200-a
4030
4200-c
Time Driven
Switch
or
Time Driven
Priority
Switch
4010
4020
OC-3
4200-b

FIG. 41

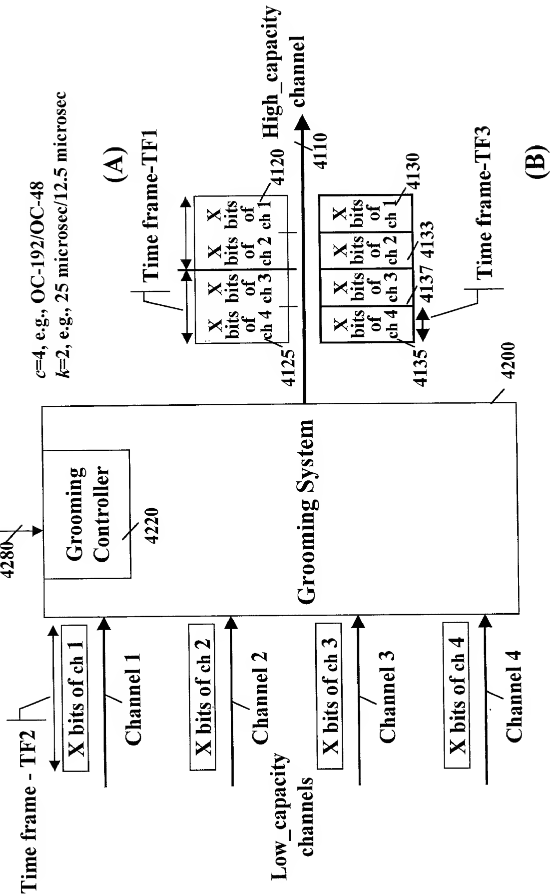

c=4, e.g., OC-192/OC-48
k=2, e.g., 25 microsec/12.5 microsec
(A)
Time frame-TF1
X bits of ch 4
X bits of ch 3
X bits of ch 2
X bits of ch 1
4120
4125
High_capacity channel
4110
X bits of ch 4
X bits of ch 3
X bits of ch 2
X bits of ch 1
4130
4133
4137
4135
Time frame-TF3
(B)
4200
CTR - 002
4280
Grooming Controller
4220
Grooming System
Time frame - TF2
X bits of ch 1
Channel 1
X bits of ch 2
Channel 2
X bits of ch 3
Channel 3
X bits of ch 4
Channel 4
Low_capacity channels

FIG. 42

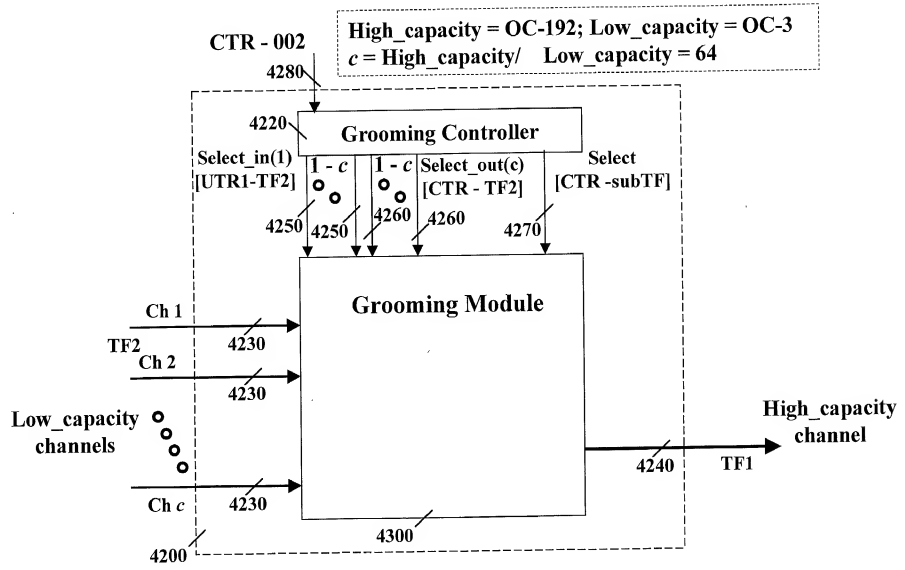


FIG. 43

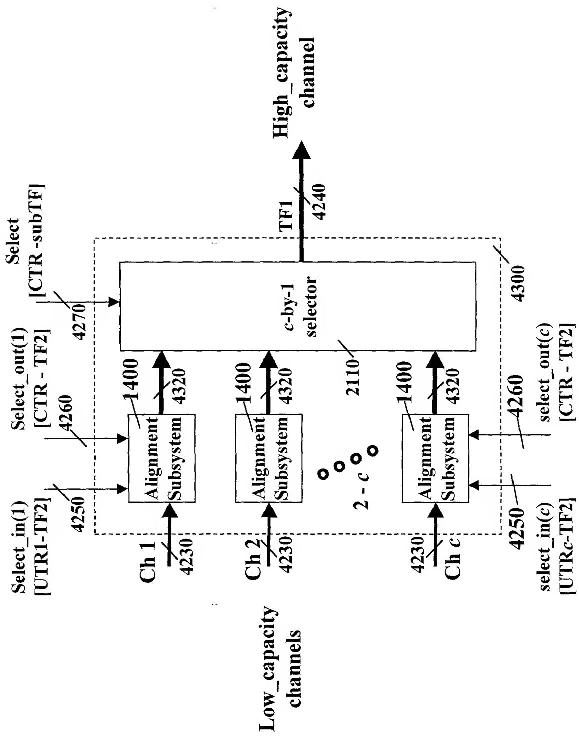

High_capacity channel
TF1
4240
Select [CTR -subTF]
4270
c-by-1 selector
2110
4300
Select_out(1) [CTR - TF2]
4260
Select_in(1) [UTR1-TF2]
4250
1400
4320
Alignment Subsystem
Alignment Subsystem
Alignment Subsystem
2 - c
Ch 1
Ch 2
Ch c
4230
select_out(c) [CTR - TF2]
select_in(c) [UTRc-TF2]
Low_capacity channels

FIG. 44

- $CC1\_length \cdot TF1 = CC2\_length \cdot TF2 = CC3\_length \cdot TF2$
- $TF2 = (SC1\_length / SC2\_length) \cdot TF1 = k \cdot TF1$, where the common cycles of $TF1$ and $TF2$ are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

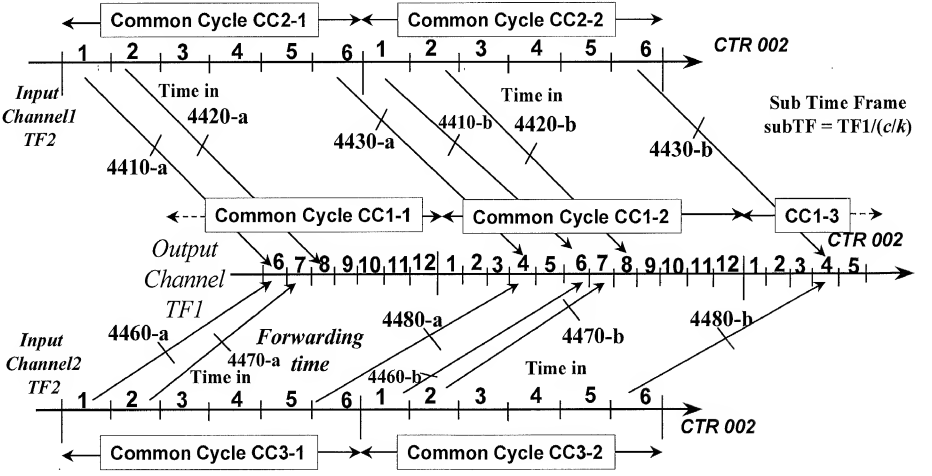


FIG. 45

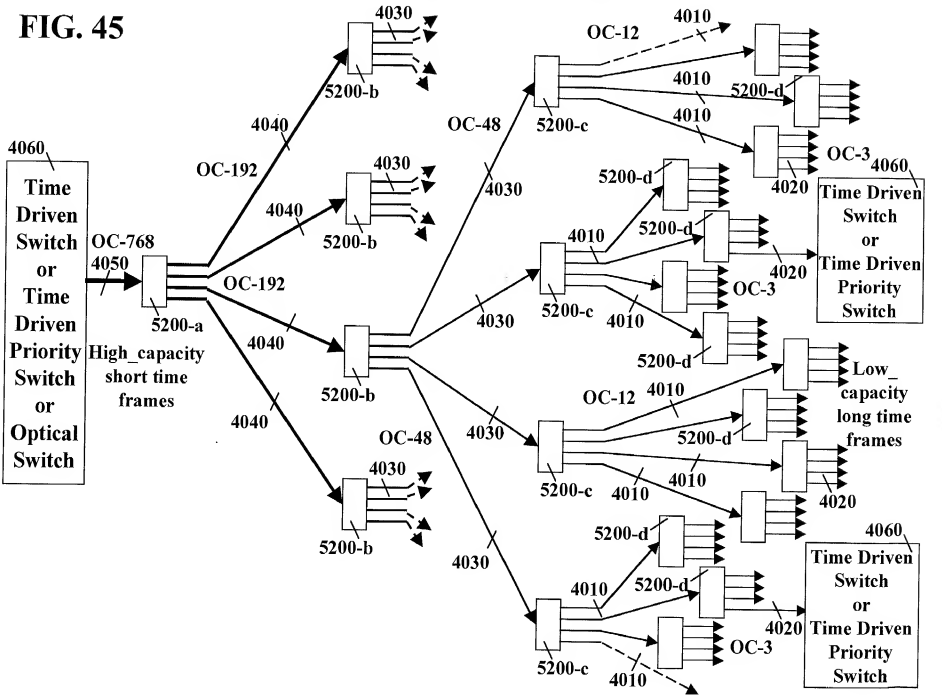
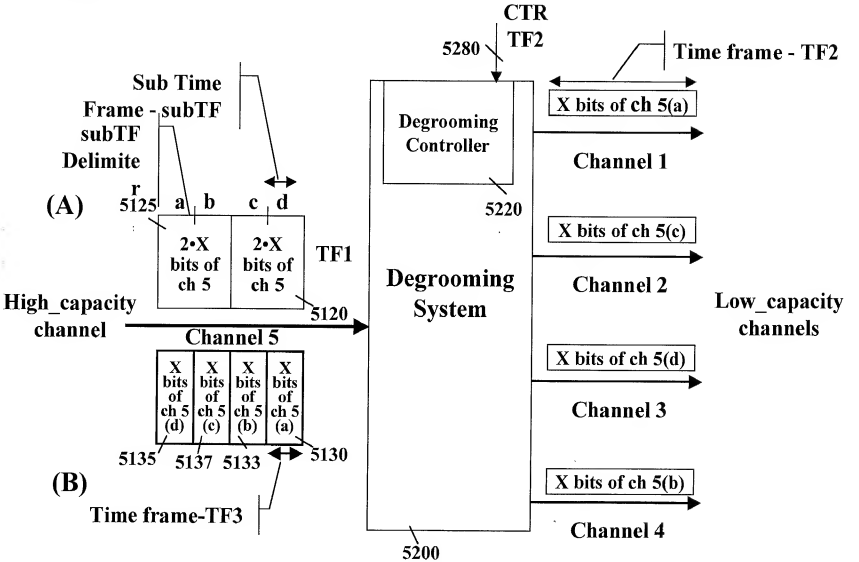


FIG. 46



c=4, e.g., OC-192/OC-48
k=2, e.g., 25 microsec/12.5 microsec

FIG. 47

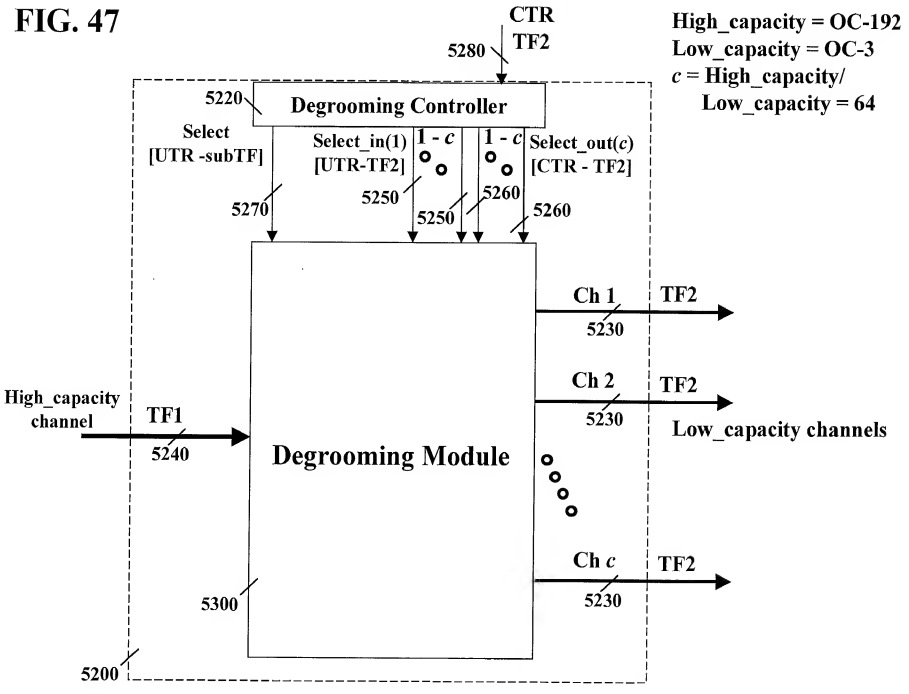


FIG. 48

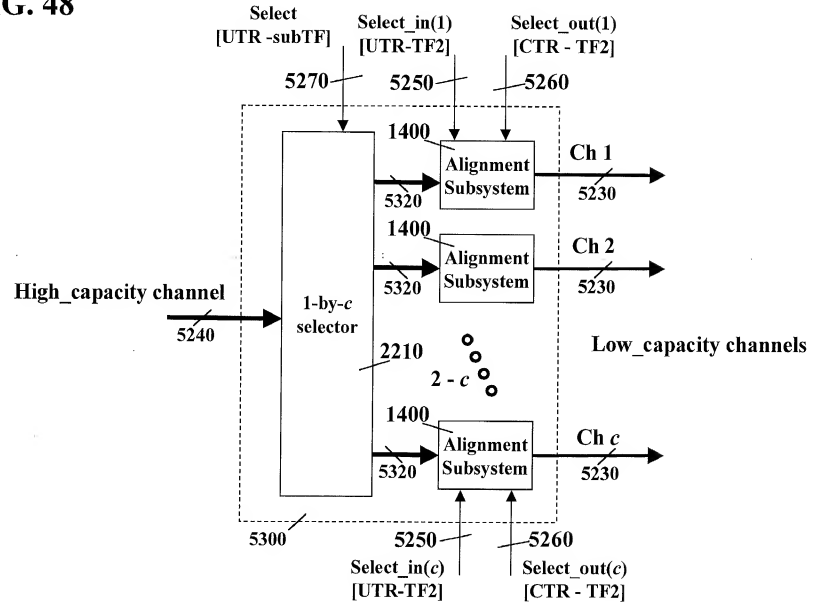

Select
[UTR -subTF]
Select_in(1)
[UTR-TF2]
Select_out(1)
[CTR - TF2]
5270
5250
5260
1400
Alignment Subsystem
Ch 1
5320
5230
1400
Alignment Subsystem
Ch 2
5320
5230
High_capacity channel
5240
1-by-c selector
2210
2 - c
Low_capacity channels
1400
Alignment Subsystem
Ch c
5320
5230
5300
5250
5260
Select_in(c)
[UTR-TF2]
Select_out(c)
[CTR - TF2]

FIG. 49

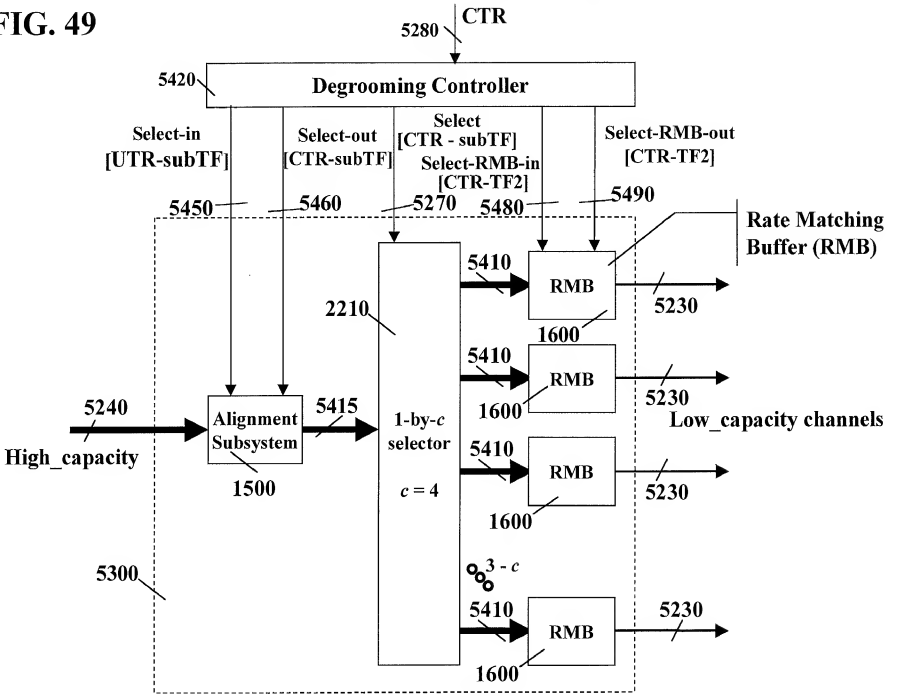


FIG. 50

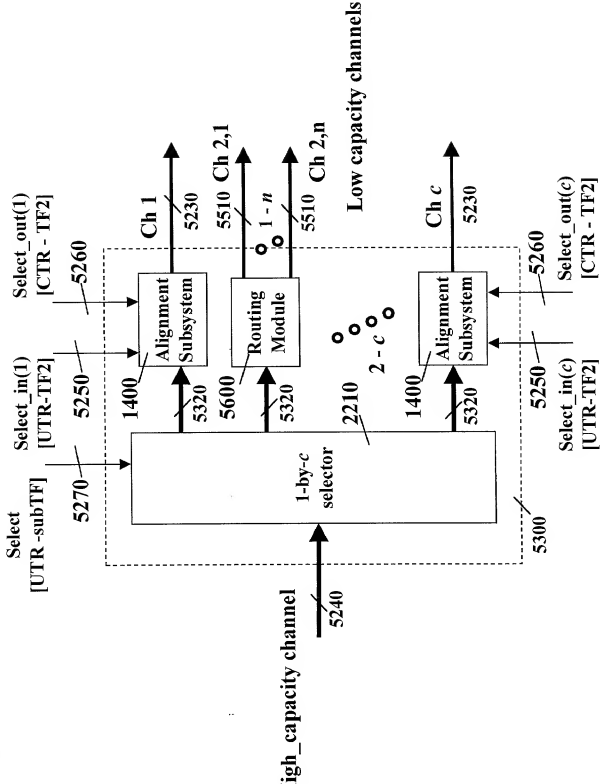

Select
[UTR -subTF]
5270
Select_in(1)
[UTR-TF2]
5250
Select_out(1)
[CTR - TF2]
5260
High_capacity channel
5240
1-by-c selector
2210
5300
1400
Alignment Subsystem
5320
Routing Module
5600
Ch 1
5230
Ch 2,1
5510
1 - n
Ch 2,n
5510
Low capacity channels
2 - c
Ch c
5230
Select_in(c)
[UTR-TF2]
Select_out(c)
[CTR - TF2]

FIG. 51

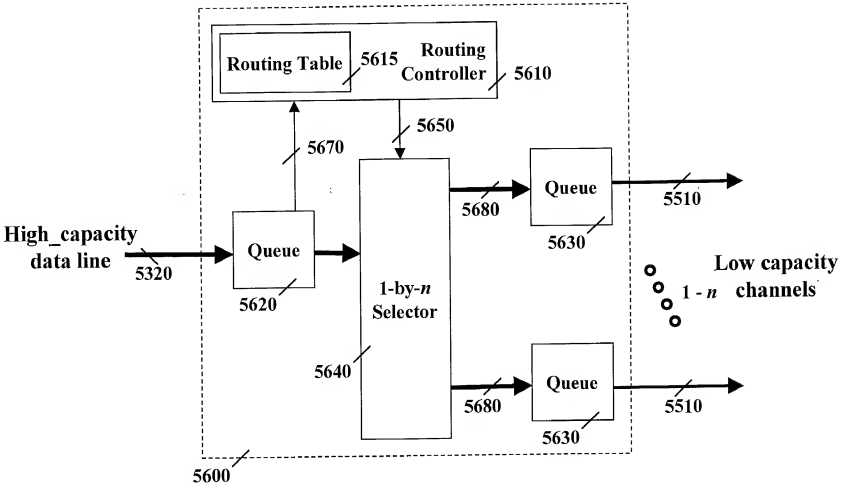


FIG. 52

- $CC1\_length \cdot TF1 = CC2\_length \cdot TF2 = CC3\_length \cdot TF2$
- $TF2 = (SC1\_length / SC2\_length) \cdot TF1 = k \cdot TF1$, where the common cycles of $TF1$ and $TF2$ are aligned with respect to UTC.

For $k = 2$ and $c = 4$ (e.g., High_capacity=OC-192, Low_capacity=OC-48):

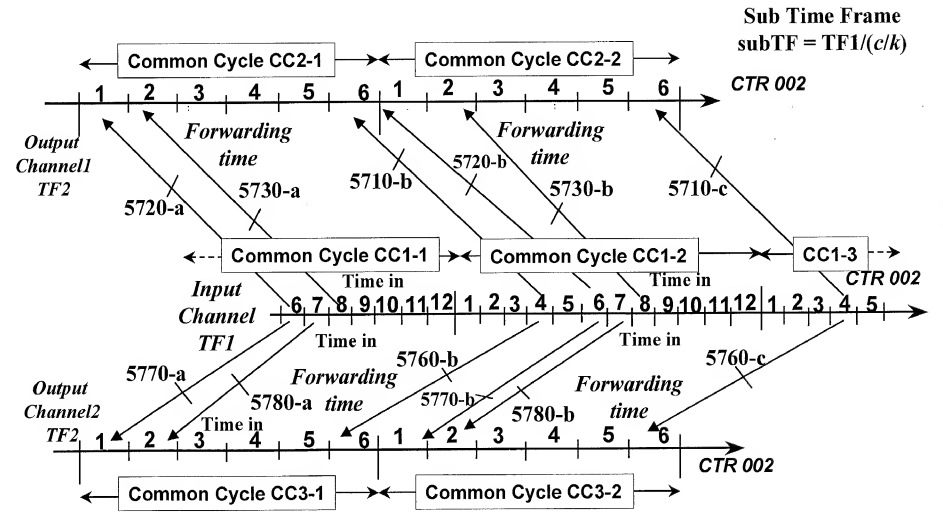


FIG. 53

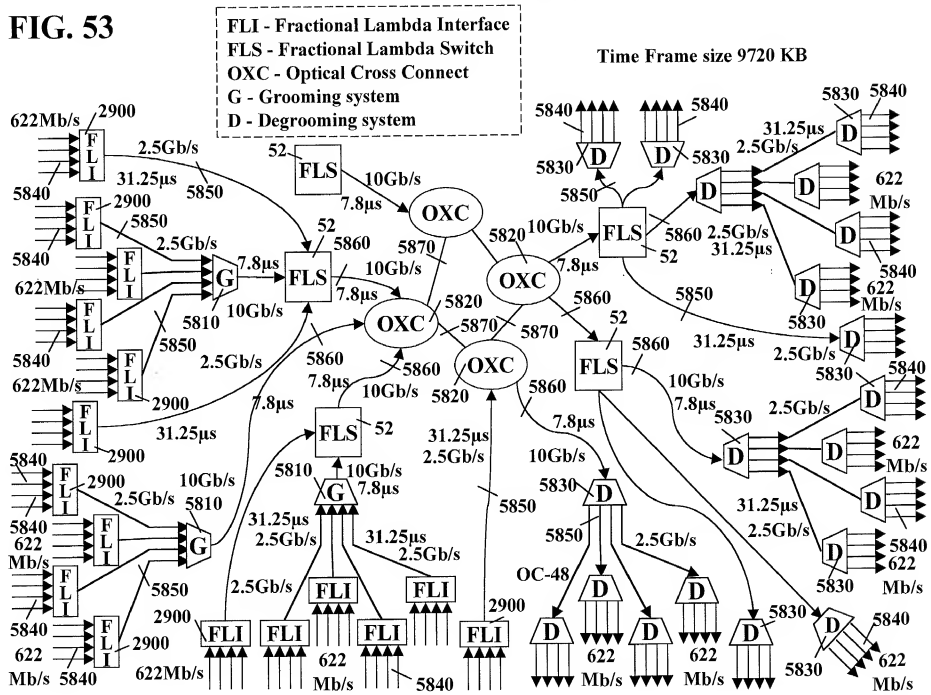


FIG. 54

FLI - Fractional Lambda Interface
FLS - Fractional Lambda Switch
OXC - Optical Cross Connect
G - Grooming system
D - Degrooming system

12 STS-1s per time frame

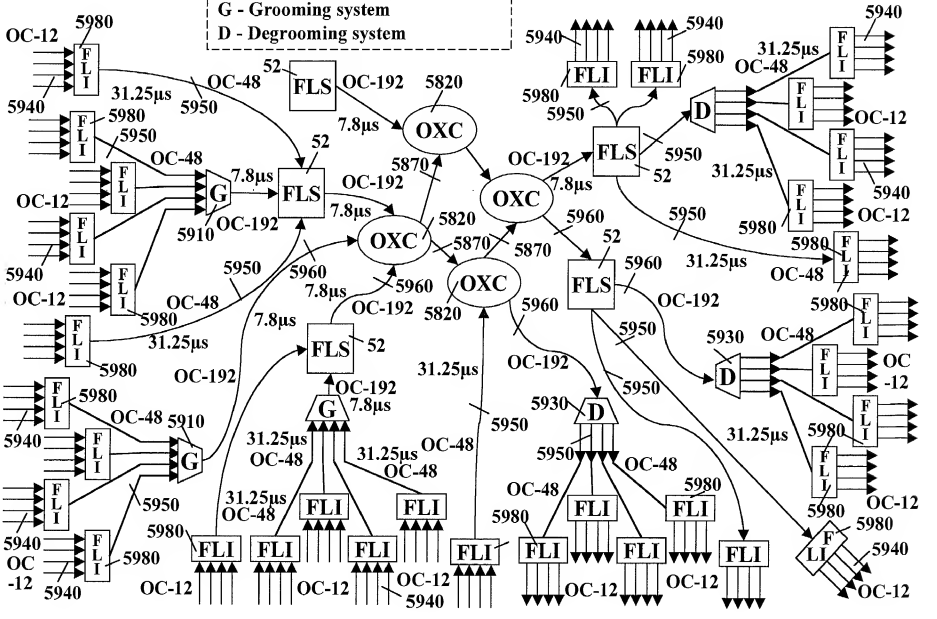


FIG. 55

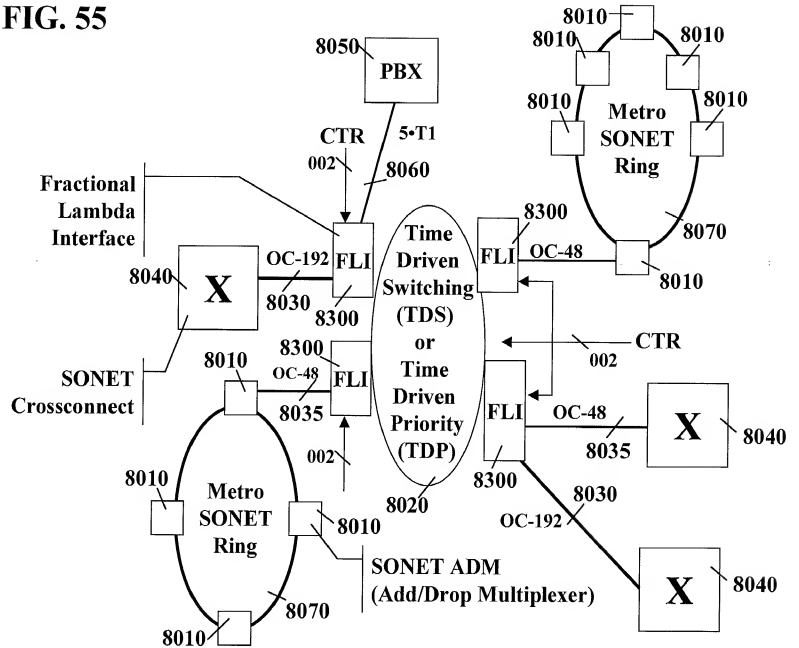
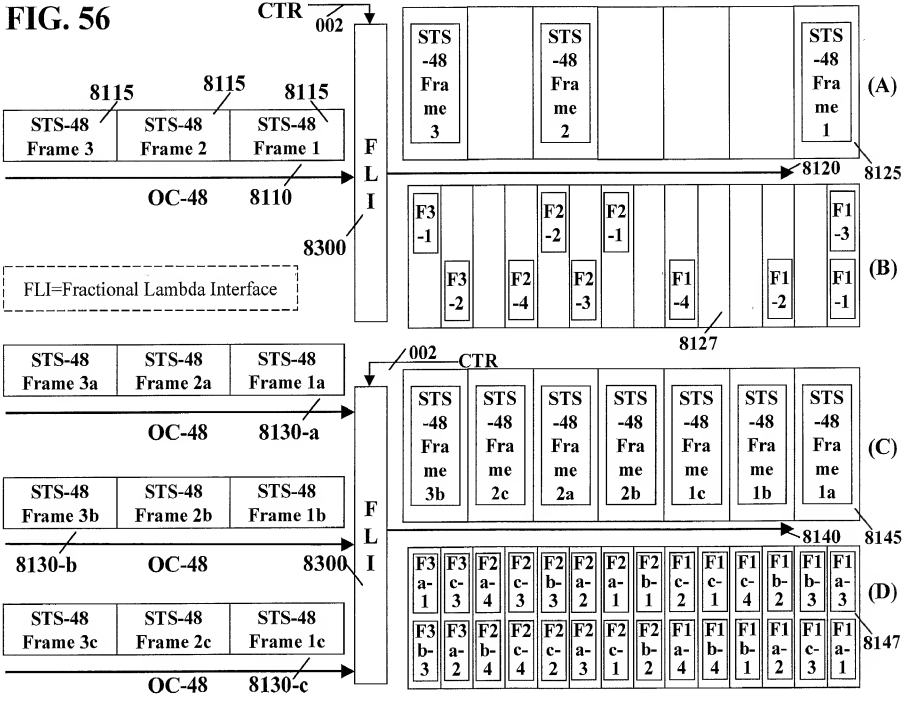

8050
PBX
CTR
002
5•T1
8060
Fractional
Lambda
Interface
8040
X
OC-192
FLI
8030
8300
Time
Driven
Switching
(TDS)
or
Time
Driven
Priority
(TDP)
8020
8300
FLI
OC-48
8035
SONET
Crossconnect
8010
002
Metro
SONET
Ring
8070
8010
8010
8010
8010
8010
8010
8010
8010
8300
FLI
OC-48
8035
CTR
002
FLI
OC-48
X
8040
8300
8030
OC-192
X
8040
SONET ADM
(Add/Drop Multiplexer)

FIG. 56



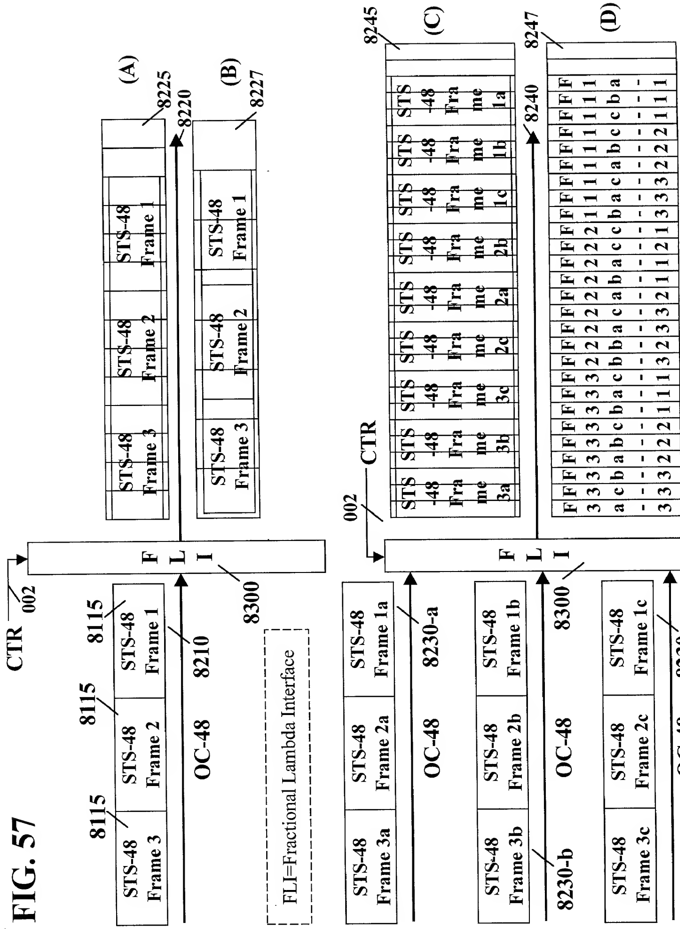

CTR
002
8115
8115
8115
STS-48 Frame 3
STS-48 Frame 2
STS-48 Frame 1
OC-48
8210
FLI
8300
8220
8225
(A)
8227
(B)
FLI=Fractional Lambda Interface
STS-48 Frame 3a
STS-48 Frame 2a
STS-48 Frame 1a
8230-a
STS-48 Frame 3b
STS-48 Frame 2b
STS-48 Frame 1b
8230-b
STS-48 Frame 3c
STS-48 Frame 2c
STS-48 Frame 1c
8230-c
8240
8245
(C)
8247
(D)

FIG. 57

FIG. 58

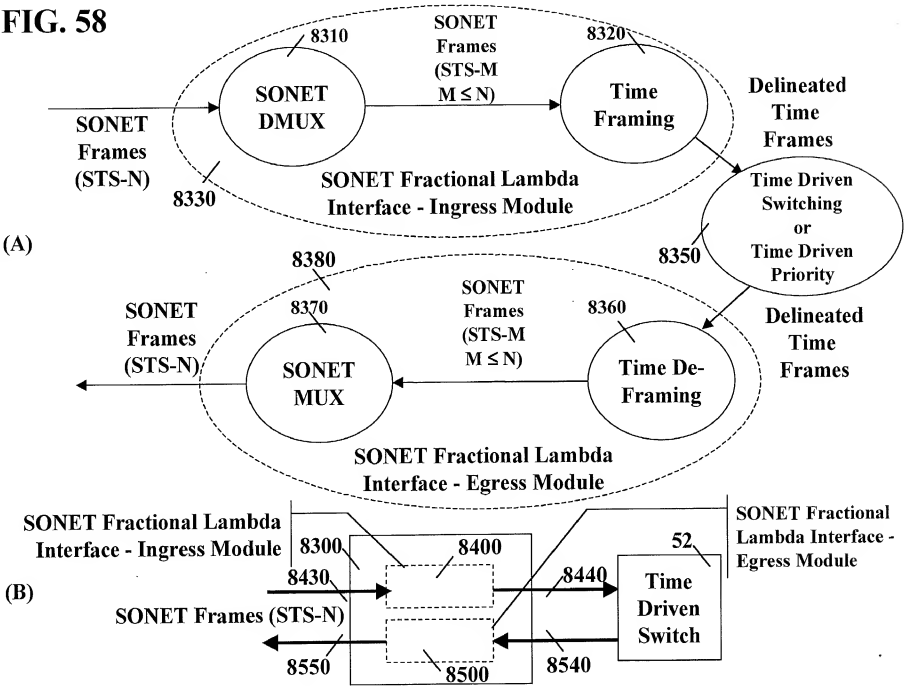


FIG. 59

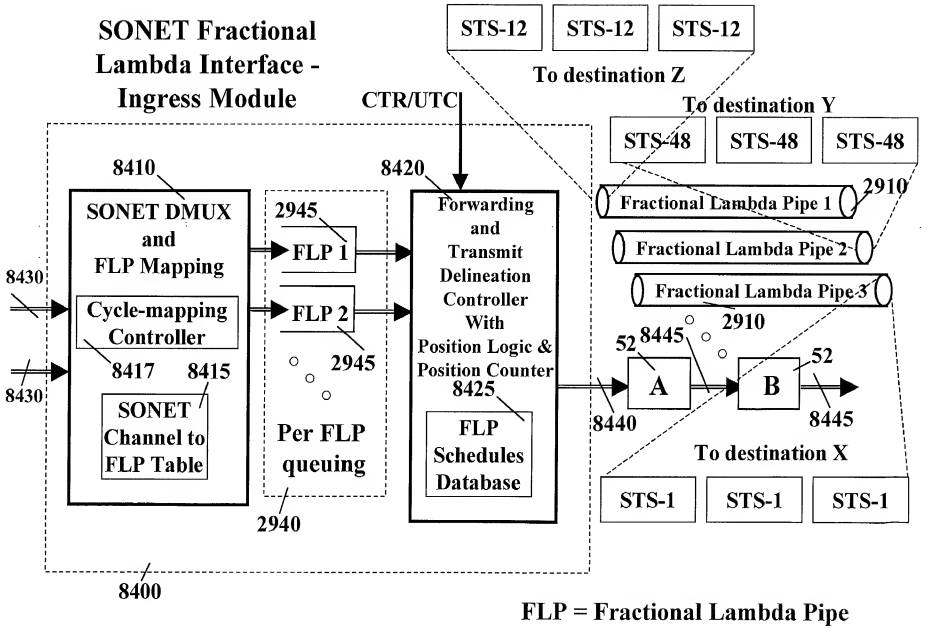


FIG. 60

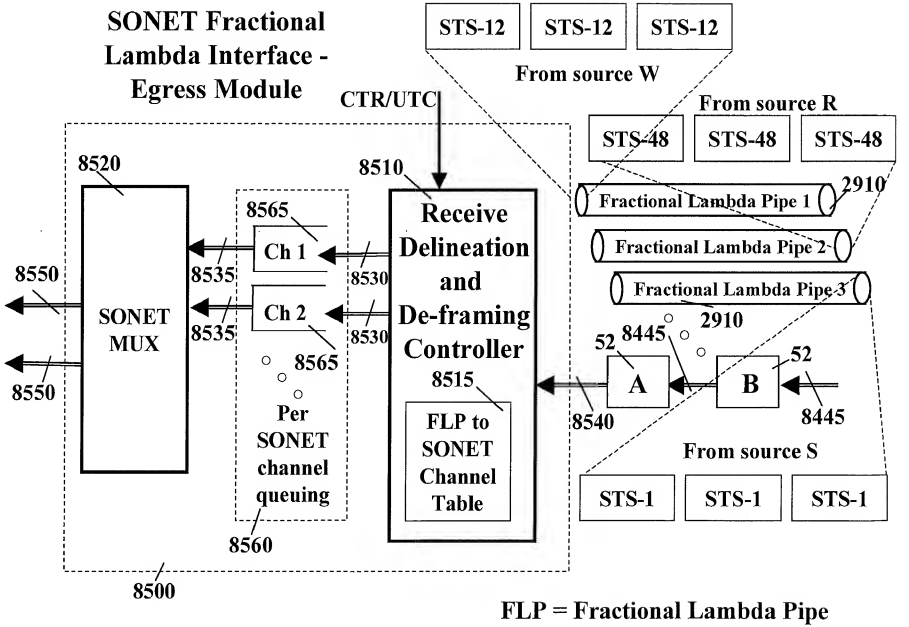


FIG. 61

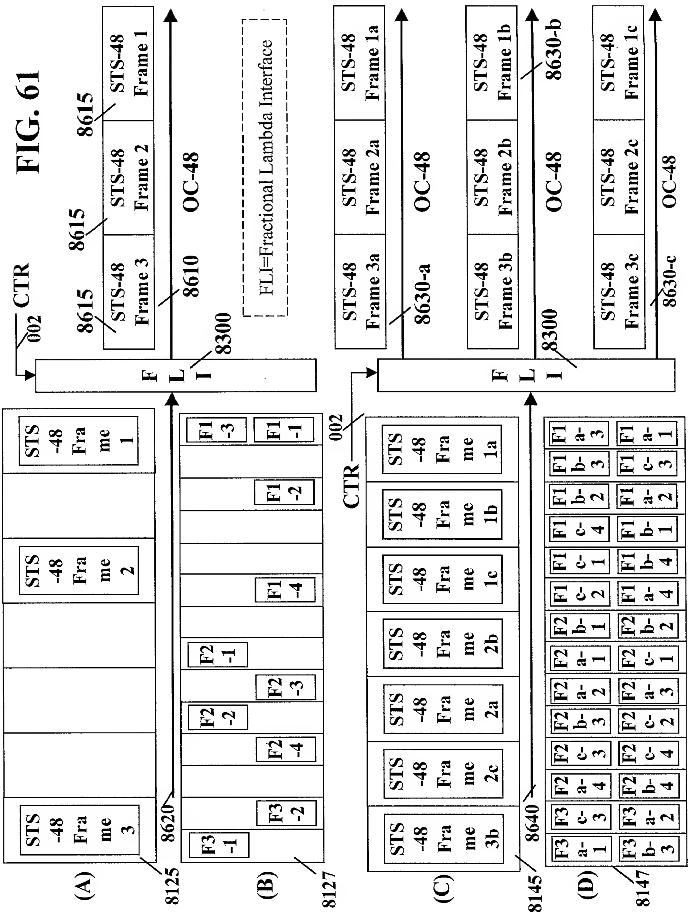
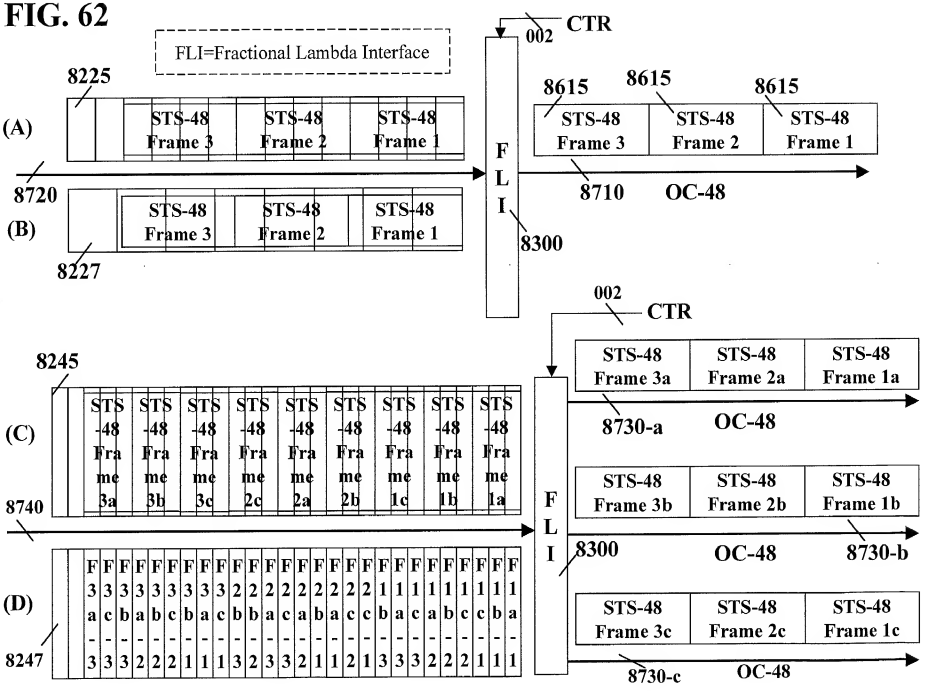

CTR
002
8615
STS-48 Frame 3
STS-48 Frame 2
STS-48 Frame 1
8610
OC-48
8300
FLI
FLI=Fractional Lambda Interface
STS-48 Frame 3a
STS-48 Frame 2a
STS-48 Frame 1a
8630-a
STS-48 Frame 3b
STS-48 Frame 2b
STS-48 Frame 1b
8630-b
STS-48 Frame 3c
STS-48 Frame 2c
STS-48 Frame 1c
8630-c
(A)
8125
(B)
8127
8620
F1 -1
F1 -2
F1 -3
F1 -4
F2 -1
F2 -2
F2 -3
F2 -4
F3 -1
F3 -2
(C)
8145
8640
(D)
8147

FIG. 62



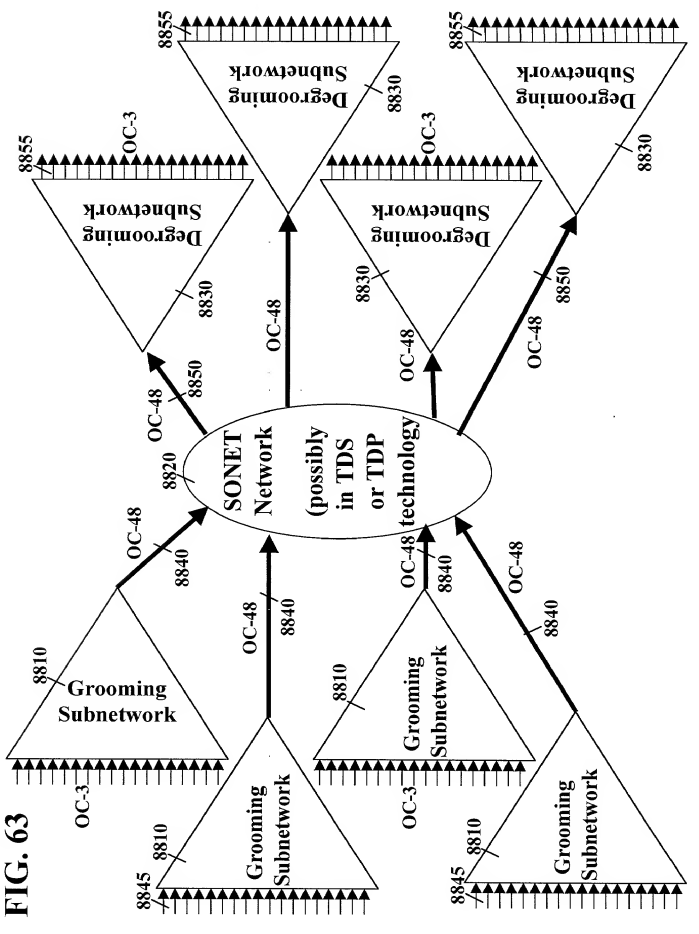

SONET Network (possibly in TDS or TDP technology)
8820
OC-48
8840
8850
8830
8855
OC-3
8810
8845
Grooming Subnetwork
Degrooming Subnetwork

FIG. 63

FIG. 64

- SONET - synchronous optical network
- Multiplexing method: byte interleaving
- Signal hierarchy: OC-N (STS-N)
  - STS-N rate: N*51.84 Mb/s
  - Frame format: 9 rows by 90*N columns
    - capacity: N*810 bytes in 125 microsecond.
    - overhead: N*27 bytes
    - payload: N*783 bytes

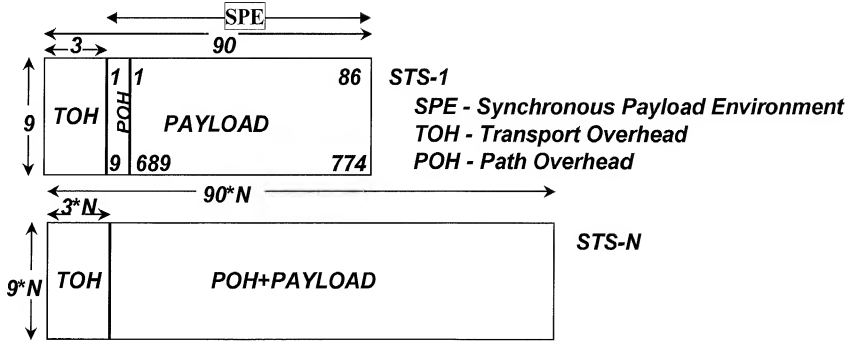


FIG. 65